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A TWO-PHASE INVESTIGATION OF LONGITUDINAL FLYING QUALITIES FOR FIGHTERS. PHASE I: THE EFFECT OF EVALUATION TECHNIQUE AND FLIGHT PHASE ON FLYING QUALITIES ASSESSMENT. PHASE II: AN EXAMPLE OF CRITERIA DEVELOPMENT, CONTROL SYSTEM DESIGN AND FLIGHT TEST EVALUATION OF FOUR CONTROL SYSTEMS USING ETA-Z, ALPHA, AND Q FEEDBACK

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A two-phase study was performed using the USAF NT-33A variable stability airplane. In Phase I of the study the effect of the evaluation technique used in the assessment of airplane flying qualities for the air combat Flight Phase was investigated. In-flight evaluations with and without a target airplane were performed for selected configurations from AFFDL-TR-70-74. The results from the evaluations with a target airplane were compared to results obtained with a target airplane and to the results

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*) in AFFDL-TR-70-74. In all cases, the evaluations performed without a target airplane were adequate to reveal potential flying qualities problems in the detailed pilot comments. There was, however, larger variability in the rating differences between the evaluations performed with and without a target. There were also significant rating differences between the evaluations performed with and without a target for about 15% of the configurations. Use of the target airplane and performance of the actual task aided the evaluation pilots in judging the consequences of the potential problems and resulted in less variability in the pilot ratings and presumably more valid evaluations. A further portion of the Phase I study was to assess the effect of the Flight Phase of the evaluation task on flying qualities evaluation results. Selected configurations from AFFDL-TR-70-74 were evaluated in the aerial refueling task using a probe and drogue system. The results of these evaluations, when compared to the results in the ACM task, indicated that the pilot ratings obtained were task-dependent in approximately one-third of the cases tested. The Phase II portion of the study was an investigation of the overall systems criteria for the flying qualities of highly augmented aircraft. A system design procedure based on the criterion of AFFDL-TR-70-74 and the requirements of MIL-F-8785B was developed. The NT-33A variable stability system (VSS) was used to simulate the longitudinal characteristics of an unaugmented high-performance fighter. Four different flight control systems, designed in accordance with the procedure developed, were mechanized around the "unaugmented" airplane represented by the NT-33A and its VSS. In-flight evaluations of the flight control systems were performed over a fighter mission profile which required wide ranges of speed and altitude, and included four fighter airplane Flight Phases: ground attack, air intercept tracking, ACM, and the landing approach. All four flight control systems received satisfactory pilot ratings for all Flight Phases.

PREFACE

This report, which was prepared for the United States Air Force by Calspan Corporation, Buffalo, New York in partial fulfillment of Contract F33615-73-C-3051, "In-Flight Simulation Investigations," describes the experimental procedure and results of the T-33 Task I under that contract.

The program was performed during the period 1 February 1973 to 14 December 1973 by the Flight Research Department of Calspan under the sponsorship of the Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Mr. J.L. Lockenour was project engineer for the USAF. Captain R. Ruffing was the USAF project manager.

This report is being published as Calspan Report No. AK-5280-F-2. The work reported in this document represents the efforts of a number of persons and organizations whom the authors wish to acknowledge:
Mr. G. Warren Hall of Calspan and Maj. Walter J. Schob, Jr., USAF were the evaluation pilots for Phase I, Mr. Rogers E. Smith and Captain Leroy B. Schroeder, USAF, were the evaluation pilots for the Phase II evaluations. Mr. Smith and Mr. Hall were the NT-33A safety pilots for Phase I and Phase II, respectively. Mr. Ronald W. Huber and Mr. Thomas J. Franclemont were responsible for the variable stability system (VSS) modification, calibration, and maintenance. The Crew Chief for the NT-33A airplane was Mr. Alva R. Schwartz.

The personnel of the Cleveland Air Route Traffic Control Center were quite instrumental in the successful completion of this flight program, especially Mr. Eugene Strauch, who handled the daily coordination of an airspace block for ACM evaluations. Mr. James Stewart and Mr. John Leacock handled the arrangements for the designation of a block of airspace known as the "Grant Flying Area," in which radar coverage of the operation was always available.

The target airplanes for this program were flown by Maj. Bob Hadfield, USAF, and Messrs. Franklin F. Eckhart and John F. Mitchell of Calspan.

Finally, the in-flight refueling evaluations would not have been possible without the able assistance of VAQ 308, NAS Alameda, California, which provided the KA-3 tanker aircraft. Lt. Richard Redd, USNR, RTU-208; Lt. Douglas Lashley, USNR, RTU-208; LCDR Philips Middleton, USNR, VAQ-208 and Mr. Gerald D. Davis, VAQ-308, all of NAS Alameda, were members of the tanker crews. Mr. Alan B Adler made the arrangements with VAQ-308 for the tanker operations.

Computer programming and processing assistance was provided by Mr. Clarence L. Messiah for identification and data reduction for the Phase II data. Mr. Floreal R. Prieto was technical editor. The Calspan Program Manager was Mr. G. Warren Hall.

This report was submitted by the authors in January 1974.

This report has been reviewed and is approved.

C.B. Westbrook
Chief, Control Criteria Branch
Air Force Flight Dynamics Laboratory

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Section I

INTRODUCTION

In several previous evaluation programs performed in the NT-33A variable stability airplane, test configurations were evaluated for the air combat Flight Phase by having experienced pilots perform maneuvers typical of air combat but without actually flying against a maneuvering target airplane. The sufficiency of this evaluation technique has been questioned, and part of this program was a comparison of evaluation results obtained by flying typical maneuvers with results obtained by actually maneuvering against a target airplane and tracking the target airplane in realistic air combat simulation. The program was designed to explore the necessity for using this technique as opposed to flying a single airplane in maneuvers that are typical of the fighter task.

Some of the previous NT-33A investigations, References 1 and 2 particularly, have also addressed the problems of higher-order control systems which have become increasingly common as complex SAS and CAS have developed. Because of differences in the control system requirements (and possibly even the variable controlled) during a given mission or Flight Phase, increased interest in the possible need for multimode flight control systems has developed (Ref. 3). Hence, the flight task, or subtask, has been recognized as a variable in overall system design requirements.

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1. T.P. Neal and R.E. Smith, "An In-Flight Investigation to Develop Control System Design Criteria for Fighter Airplanes," AFFDL-TR-70-74, June 1970.

2. D.A. Di Franco, "In-Flight Investigation of the Effects of Higher-Order Control System Dynamics on Longitudinal Handling Qualities," AFFDL-TR-68-90, July 1968.

3. R.P. Quinlivan, "Multimode Flight Control Definition Study," AFFDL-TR-72-55, May 1972.

The first phase of the current investigation was a study to determine the effect that the evaluation task may have on handling qualities assessments. This was accomplished by evaluating selected configurations from the study of Reference 1 in the air combat task with "target" aircraft and in the aerial refueling task by performing actual in-flight refueling hook-ups.

The second phase of the current study, an investigation of overall systems criteria for the flying qualities of highly augmented aircraft, was performed by evaluating four different control augmentation systems over a fighter airplane mission profile which included the evaluation of several fighter tasks. This portion of the program consisted of the design, mechanization and in-flight evaluation of four separate flight control system concepts using combinations of normal acceleration, angle of attack and pitch rate feedback together with forward loop gain scheduling and signal shaping. Each of the control augmentation systems was designed to provide Level 1 longitudinal flying qualities over a complete fighter mission profile including the ground attack, air-to-air intercept, air combat maneuvering, and landing approach tasks. The flight control system designs were applied to an airplane having the longitudinal basic airframe characteristics of an unaugmented, high performance fighter aircraft.

From the above discussion it is evident that several related but separate questions should be the objective of the current investigation. For this reason the in-flight experiment was conducted in two phases as follows:

Phase I - an investigation to explore the effect that the evaluation task may have on handling qualities assessments. In-flight evaluations were performed for air combat with and without a target airplane and for aerial refueling.

Phase II - an investigation of overall systems criteria for the flying qualities of highly augmented aircraft.

The entire current investigation, however, was heavily based on work previously accomplished in Reference 1. Phase I involved the re-evaluation of selected configurations from Reference 1. In Phase II, the criteria for the pitch response characteristics used for flight control system design were developed from work reported in Reference 1 as well as from the requirements of MIL-F-8785B.

This report presents a detailed description of both Phase I and Phase II of the experiment and the results obtained. Beginning with Section III, the two phases of the overall experiment are described and reported separately.

Section II

BACKGROUND

2.1 REVIEW OF THE EXPERIMENT DESIGN OF REFERENCE 1

Since the configurations for Phase I of the current study were selected directly from those presented in Reference 1, it is necessary to review rather thoroughly the experimental design presented in Reference 1.

The purpose of the referenced study was to provide data on the effects of flight control system (FCS) dynamics on fighter airplane flying qualities in the combat task and to develop a preliminary set of criteria for the design of flight control systems. Since a previous in-flight experiment, Reference 2, had studied the effects of FCS transfer functions of second to fifth order, the study of Reference 1 was devoted to the effects of first-order FCS poles and zeroes.

Eight basic short-period configurations were selected to span fairly wide ranges relative to the requirements of MIL-F-8785B. Six additional short-period configurations were selected which had rather extreme values of ζ_{sp} and ω_{sp} to compare with the short-period requirements of MIL-F-8785B, where the data supporting the requirements was sparse. Five of the basic short period and three of the additional configurations were flown at an indicated speed of 250 knots (n/α = 18.5 g/rad). The remaining three basic configurations and three additional configurations were flown at 350 knots (n/α = 50 g/rad).

All eight basic configurations were evaluated with various first-order leads and lags. Figure 1, which was reproduced from Reference 1, represents the pitch attitude response to stick force inputs for these basic configurations. Figure 1 also indicates that a second-order FCS pole was included, with its natural frequency fixed at 63 rad/sec for most of the experiment.

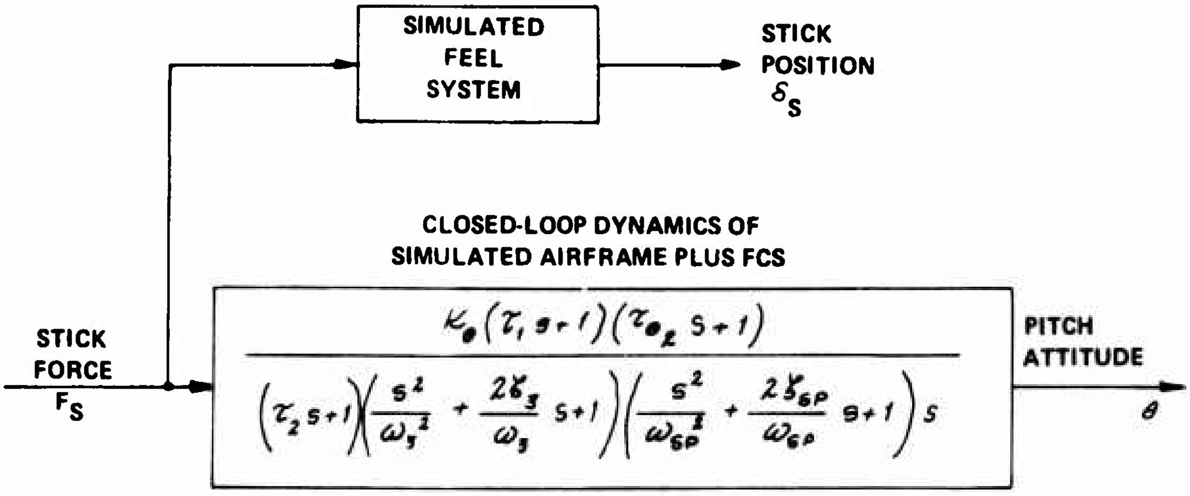
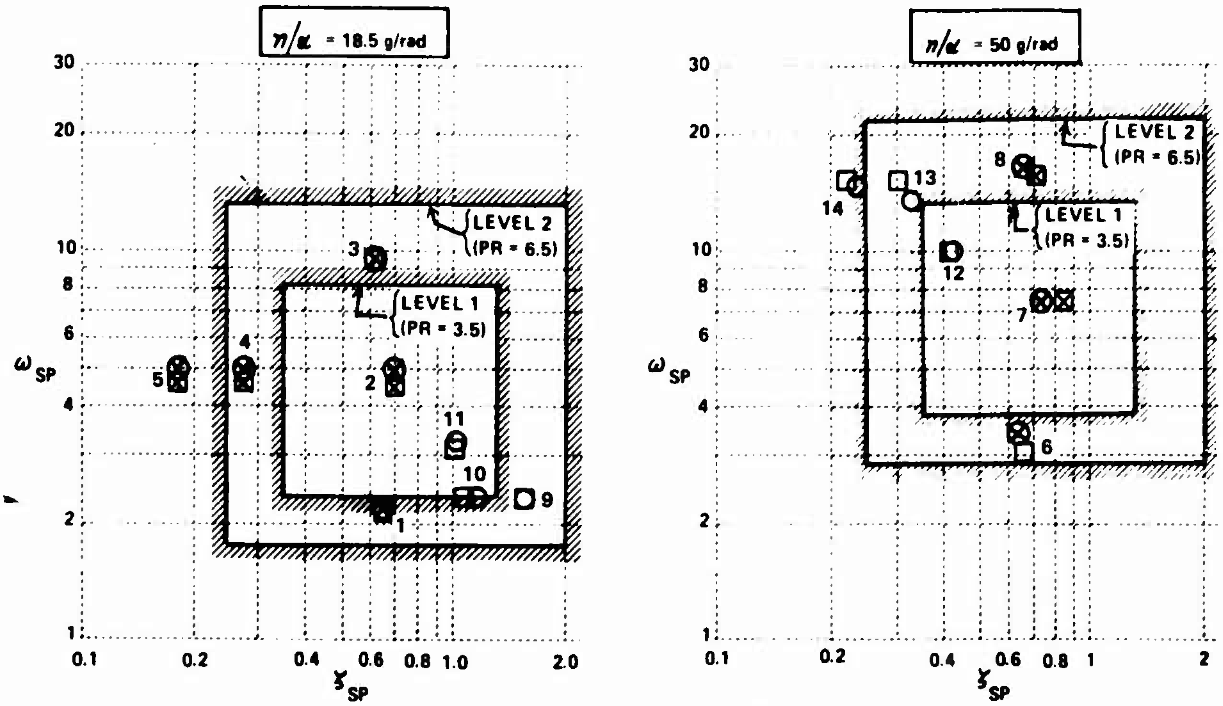


Figure 1 BLOCK DIAGRAM FOR BASIC CONFIGURATIONS SIMULATED



LEGEND	
⊗ , ⊠	– EIGHT BASIC CONFIGURATIONS
O , ☐	– SIX ADDITIONAL CONFIGURATIONS
⊗ , O	– REFERENCE 1 DATA
⊠ , ☐	– DATA FROM CURRENT EXPERIMENT

Figure 2 COMPARISON OF EIGHT BASIC SHORT–PERIOD CONFIGURATIONS AND SIX ADDITIONAL SHORT–PERIOD CONFIGURATIONS WITH MIL-F-8785B REQUIREMENTS

The eight basic and six additional short-period configurations are compared to MIL-F-8785B short-period requirements on Figure 2. The six additional configurations are identified as configurations 9 through 14. The eight basic short period configurations evaluated in the study of Reference 1, and the FCS configurations obtained through the addition of first-order leads and lags to these short-period configurations, are identified in Figure 3, also reproduced from Reference 1.

The significance of the parameters $\frac{1}{\tau_1}$, $\frac{1}{\tau_2}$ and ω_3 can be seen by reference to the block diagram, Figure 1. The values of τ_1 and τ_2 simulated in the study of Reference 1 were chosen to span the range of values found to be typical in FCS designs.

The six additional configurations, 9 through 14, were mechanized differently from the configurations shown in Figure 3; i.e., stick position commands were used instead of force commands. Also, these configurations did not include any first-order lead or lag. Figure 4 is a block diagram reproduced from Reference 1, which shows the pitch-attitude dynamics for the six additional configurations. Appendix IV of Reference 1 presents a detailed discussion of airplane longitudinal transfer functions and equations of motion. The relationships will not, therefore, be repeated here. Also, Appendix V of Reference 1 explains how the simulated configurations were mechanized in the variable stability NT-33A and how the longitudinal characteristics described above were measured.

2.1.1 Pilot Comment Data From Reference 1

Evaluations of the configurations shown in Figure 3 and the six additional configurations were conducted by having the evaluation pilots perform maneuvers representative of those tasks anticipated in the fighter mission. The evaluation maneuvers included gross maneuvering tasks and precision tracking tasks, but without a target airplane. Pilot comments and ratings

CONTROL SYSTEM CHARACTERISTICS			SHORT PERIOD CHARACTERISTICS							
			n/α = 18.5 g/RAD, V_{ind} = 250 KT, $1/\tau_{\theta_2}$ = 1.25 SEC^{-1}					n/α = 50 g/RAD, V_{ind} = 350 KT, $1/\tau_{\theta_2}$ = 2.4 SEC^{-1}		
			ω_{SP}/ζ_{SP}					ω_{SP}/ζ_{SP}		
$1/\tau_1$	$1/\tau_2$	ω_3	2.2/.69	4.9/.70	9.7/.63	5.0/.28	5.1/.18	3.4/.67	7.3/.73	16.5/.69
0.5	2	63	1A							
0.8	3.3							6A		
2	5		1B	2A						
3.3	8							6B	7A	
5	12			2C						
8	19	↓							7B	
∞	∞	75	1D	2D	3A	4A	5A	6C	7C	8A
	19	63							7D	8B
	12			2E	3B	4B	5B			
	8							6D	7E	8C
	5		1E	2F	3C	4C	5C			
	3.3							6E	7F	8D
	2		1F	2H	3D	4D	5D		7G	
	0.8							6F	7H	8E
↓	0.5	↓	1G	2J	3E	4E	5E			
2	5	16	1C	2B						
∞	5			2G						
↓	2	↓		2I						

NOTE: (1) Numbers/Letters Indicate Configurations Simulated

(2) ζ_3 =.75 for ω_3 = 63, 16; ζ_3 =.67 for ω_3 =75

Figure 3 BASIC FCS/SHORT–PERIOD CONFIGURATIONS SIMULATED IN AFFDL-TR-70-74 (REF. 1)

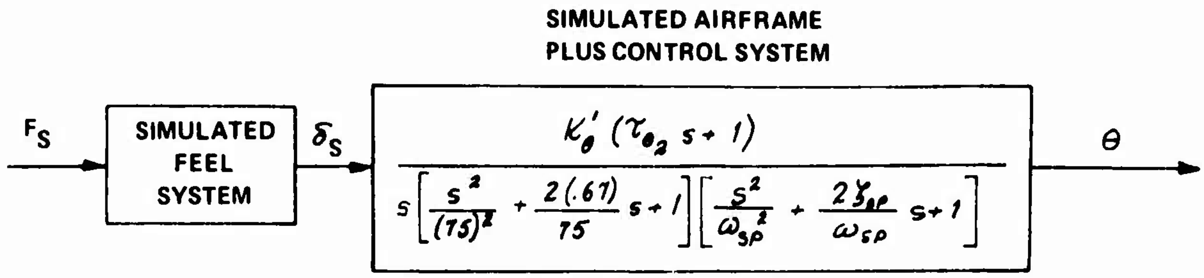


Figure 4 **BLOCK DIAGRAM FOR THE SIX ADDITIONAL CONFIGURATIONS**

were recorded for analysis. During each evaluation, the pilot was allowed to select the elevator to control input gearing, thereby selecting the stick force per unit normal acceleration, F_S/n. The selected values of F_S/n were recorded as part of the data obtained.

The pilot comments indicated that the primary concern of the pilot was his ability to quickly change pitch attitude in acquiring a target and precisely controlling pitch during tracking maneuvers. Normal acceleration control was certainly of concern to the pilot but this response was used more in the sense of a measure of maneuver magnitude and as the maneuver limiting factor. The pilots evaluated the total system. They were not aware of the individual elements in the combination of control system and short period being simulated in the evaluation of any given configuration. A summary of the pilot rating and F_S/n results obtained is presented in Section IV of this report so that the results of the current study can be directly compared to those previously obtained. When making such a comparison, however, the reader must remember that the pilot comment data is no less important than the pilot rating data. Refer to Appendix I of Reference 1 for pilot comment summaries obtained from the referenced study, Bode plots, and time histories for each configuration.

2.1.2 Pilot-In-The-Loop Analysis

The major result from Neal and Smith's work was the development of control system design criterion. An extension of this criterion has been proposed, Reference 4, as a revision for the pitch dynamic requirements of MIL-F-8785B. The basic criteria discussed in Reference 1 involved a closed-loop analysis of the pilot-airplane combination. A simplified procedure, based on measurements made from the airplane response alone, was also developed. Reference 4 thoroughly reviews the design criteria and suggested modifications to the simplified criterion for the pitch dynamic response requirements of MIL-F-8785B. Briefly, closed-loop performance standards were established for pitch attitude control. The Nichols chart was then used to convert the open-loop characteristics to closed loop by overlaying a plot of the open-loop amplitude versus phase on the Nichols chart. Adjustment could then be made to pilot gain and pilot compensation to meet the performance standards. Since the design criterion was stated in terms of the frequency response characteristics of the airplane plus control system, rather than in terms of the conventional aircraft modal characteristics, the criterion is applicable to basic aircraft as well as to highly augmented aircraft. The data for each configuration evaluated was analyzed using the pilot-in-the-loop analysis techniques developed, and the resulting parameters were correlated with the pilot comment data.

2.2 PURPOSE OF THE CURRENT STUDY

Considerable data have been collected and analyzed to determine the effects of basic airplane dynamics and airplane plus FCS dynamics on the precision tracking and air combat maneuvering tasks. Most of this work, however, has been accomplished by having experienced pilots perform maneuvers

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4. C.R. Chalk, et al., "Revisions to MIL-F-8785B(ASG) proposed by Cornell Aeronautical Laboratory, Inc. under Contract F33615-71-C-1254," AFFDL-TR-72-41, April 1973.

that were typical of the air combat Flight Phase, but without a target airplane to acquire and track.

Since the sufficiency of this technique has been questioned, it was necessary to obtain data by actually maneuvering against a target airplane and tracking the target airplane, so that the results could be compared with those obtained by performing typical maneuvers. Also, the flight task, or subtask, has been recognized as a variable in overall system design requirements. Of course, the importance of the task, the precise definition of the task and its relation to the overall mission requirements, has long been recognized as a parameter in handling qualities assessments. Evaluation task considerations have been thoroughly outlined in Reference 5. There has been little attention, however, toward investigations where the evaluation task was one of the study variables.

The purpose of Phase I of the current study, therefore, was to determine the effect that the evaluation task may have on the handling qualities assessments. To obtain data to investigate the effect of the evaluation task, selected configurations from the study of Reference 1 were re-evaluated in a mock air combat maneuvering task using a target aircraft to maneuver against and track. Selected configurations were also evaluated in the aerial refueling task so that the effect of this evaluation task could also be investigated.

The purpose of Phase II was to investigate the overall system criteria for the flying qualities of highly augmented aircraft. This included the development of design criteria for the overall system that would be applicable to a fighter mission profile with several typical fighter tasks. Mechanization and evaluation of control systems meeting the design criteria was a major goal of this phase of the investigation. The data obtained could then be used to verify and further validate the applicable proposed requirements in Reference 4. There was some overlap in the two phases of the program; i.e., both phases involved the evaluation of configurations in which higher order control system concepts were applied.

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5. G.E. Cooper and R.P. Harper, Jr., "The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities," NASA TN-D-5153, April 1969.

Section III
DESCRIPTION OF PHASE I EXPERIMENT

3.1 TEST PROGRAM

Basically two evaluation tasks were performed in this experiment:

1. Air combat maneuvering (ACM) and tracking.

2. Aerial refueling in which actual hook-ups were performed using a probe and drogue system.

The ACM and tracking task was, however, evaluated using two techniques. One technique was the actual acquisition and tracking of a target airplane in a mock ACM situation and the second was the same procedure used in the study of Reference 1; i.e., the performance of maneuvers typical of the air combat task and a programmed pitch attitude tracking task using a cockpit instrument display.

3.1.1 Configurations Evaluated

The evaluation configurations for all the above tasks were selected from the configurations shown in Figures 2 and 3. All these configurations had been previously evaluated during the study of Reference 1. Every effort was made to duplicate the previously evaluated characteristics for each configuration. Small differences were noted in the short period frequency, ω_{sp}, and damping ratio, ζ_{sp}, in the current program as opposed to the referenced study. Figure 5 shows the configurations evaluated in the current study and the actual short-period and FCS characteristics obtained. The letters, T, N and A in the blocks of Figure 5 indicate whether the configuration was evaluated with a target airplane, indicated by T; without a target airplane, indicated by N; or in the aerial refueling task, indicated by A. Figure 5 is

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS							
				$n/\alpha \approx 18.5$ g/rad $1/T_{\theta_2} = 1.25$ sec^{-1}					$n/\alpha \approx 50$ g/rad $1/T_{\theta_2} = 2.4$ sec^{-1}		
				ω_{sp}/ζ_{sp}					ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.2/0.70	4.5/0.72	9.5/0.63	4.5/0.29	4.7/0.18	3.0/0.68	7.3/0.85	16.0/0.73
2	5	63	0.75	1B TNA	2A TNA						
3.3	8								6B TN		
5	12				2C TN						
∞	∞	75	0.67	1D TNA	2D TNA	3A T	4A TNA	5A T A	6C TN	7C T	8A T
	19	63	0.75								8B
	12				2E T						
	8								6D TN		
	5			1E TNA	2F TN						
	3.3									7F T	8D T
	2				2H T	3D T	4D TNA	5D A			
	0.5				2J TNA			5E TNA			

SIX ADDITIONAL CONFIGURATIONS: STICK POSITION COMMANDS USED

				ω_{sp}/ζ_{sp}					ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.3/1.7	2.3/1.1	3.2/1.1			10.0/0.44	15.0/0.30	16.0/0.21
∞	∞	75	0.67	9 T A	10 T A	11 TNA			12 TN	13 TN	14 TN

NOTE: (1) NUMBERS/LETTERS IDENTIFY CONFIGURATION SIMULATED
(2) T INDICATES EVALUATED WITH TARGET AIRCRAFT
N INDICATES EVALUATED WITHOUT TARGET AIRCRAFT
A INDICATES EVALUATED IN AERIAL REFUELING TASK

Figure 5 FCS/SHORT PERIOD CONFIGURATIONS EVALUATED IN CURRENT EXPERIMENT

presented in the same format and with the same configuration identification nomenclature as Figure 3, so that they can easily be compared. The control system characteristics are also the same as those shown in Figure 3.

In the current study, 30 configurations were evaluated in the ACM/tracking task with a target airplane, and 19 configurations were evaluated in ACM/tracking without a target airplane. Fourteen configurations were evaluated in the aerial refueling task. The configurations were selected to span the range of short-period and FCS dynamics evaluated previously. Because of the number of different tasks to be performed, it was not possible in this investigation to evaluate all the configurations of Reference 1. The original intent was to perform evaluations only in the ACM task with a target airplane and compare the results to those obtained in Reference 1. Because of small differences obtained in the short-period characteristics in the current program as compared to the reference study, it was important to also conduct evaluations without a target airplane. The result was that comparisons of data with a target airplane can be made to no target data obtained in both the current experiment and the data previously obtained.

The aerial refueling task was accomplished only for selected cases with $n/\alpha \approx$ 18.5 g/rad. These configurations were evaluated at an indicated airspeed of 250 knots. The $n/\alpha \approx 50$ g/rad cases required an indicated airspeed of 350 knots which exceeded the KA-3 speed limitations for the refueling drogue.

3.1.2 Evaluation Pilots and Number of Evaluations

Two evaluation pilots participated in this phase of the program and were designated as Pilot A and Pilot B. A summary of their backgrounds is as follows:

Pilot A: A Calspan research pilot with over 3500 hours of diversified flying time including 2400 hours in fighter type aircraft. He has extensive experience as an evaluation pilot in handling qualities experiments employing variable stability airplanes. He has previously served as evaluation pilot in six in-flight investigations of handling qualities of fighter aircraft and several investigations of aircraft other than fighters. This pilot participated in the Reference 1 experiment, and was then designated Pilot W.

Pilot B: A USAF test pilot with over 4400 hours of flying time including 3300 hours in fighter type aircraft. He is a graduate of the USAF Aerospace Research Pilot School where he also served as a flight and academic instructor for four years. His recent experience includes weapon and weapon system test experience in fighter aircraft and air-to-air F-15 simulator experience against a threat aircraft. He also has recent actual fighter combat experience.

Pilot A completed 35 evaluations in the ACM task with a target airplane,of which five were repeat evaluations. He also completed 18 evaluations in the ACM task without a target airplane and 24 evaluations in the aerial refueling task, of which ten were repeat evaluations. Pilot B completed six evaluations in the ACM task with a target airplane and five evaluations without a target airplane. It was intended for Pilot B to do a much larger share of the evaluations, but scheduling difficulties precluded his further participation.

The total number of evaluations was 64 in the ACM task and 24 in the aerial refueling task. The evaluations were accomplished in 50.1 flying hours and 34 flights, of which seven flights were calibration, practice evaluation, or demonstration flights.

3.1.3 Conduct of Evaluations

Meaningful evaluations can be performed only after a clear understanding of the mission, and the circumstances under which it is to be performed. The evaluation pilot must known what he is to perform and what he is required to accomplish with the airplane. After the mission has been defined, the relationship between the simulation situation, its limitations, and the real mission must be carefully examined and understood. The basic mission in this investigation was that of an air superiority fighter with a limit load factor of 7. The evaluation maneuvers, both with and without a target airplane, were selected as representative of the air-to-air combat flight phase. The mission was carefully discussed with the evaluation pilots to ensure that each pilot would evaluate the configurations for the same mission requirements.

Although the overall fighter mission involves many tasks, the airplane handling qualities can be evaluated by having the evaluation pilot perform representative maneuvers. In this experiment, the evaluation pilot performed the task of acquiring the target airplane in his gun sight and tracking the target while closing the range to the target, but in a standardized, closely controlled manner. In the aerial refueling, the actual task was accomplished, except that no fuel was transferred. Numerous hook-ups were, however, made with the tanker airplane. For the ACM task without a target, the pilot evaluation tasks, with the exception of ground attack, were those published in Reference 1. This was done to repeat as nearly as possible the evaluations performed in the study of Reference 1, so that the results would be comparable.

During the first half of the study of Reference 1, the evaluation pilot was free to select the elevator to control input gearing of his choice.

In doing so, the pilot selected the stick force per unit normal acceleration, F_s/n. To select the best gearing for the task, the pilot really had to conduct a miniature investigation since the steady stick forces obtained, F_s/n, and the initial forces associated with a control input, which affect the precision tracking capability, may result in a conflict. During the second half of the referenced study, the evaluation pilot also selected the gearing, but was limited to a range of approximately 4.5 to 7 lb/g. If the pilot violated the limit in his selection process, then the limiting value was used. The pilot was asked to comment on any problems or compromises associated with his gearing selection.

In the current experiment, each configuration was assigned an elevator gearing selected from the data of Reference 1. Because Pilot A of the current experiment was Pilot W of the referenced experiment, selection of elevator gearing was based on his previous selections. For configurations not previously evaluated by Pilot A, a value selected by Pilot M in Reference 1 was used in the current experiment. In a few cases, a given configuration was evaluated only once (by Pilot M) in the study of Reference 1, which limited the choice of F_s/n in the current experiment.

In the current experiment, the evaluation pilot was not prohibited from re-selecting the elevator to control input gearing, but he was requested not to unless, in his estimation, the gearing was unsatisfactory and a degrading factor on the handling qualities of the configuration or the conduct of the evaluation. Therefore, the values of F_s/n obtained in the current experiment are, for the most part, similar to those obtained in the study of Reference 1. The values presented in the data and results were measured from the data recorded in the current experiment, and differ slightly from the values previously reported. The evaluation pilot was asked to comment on the pre-selected elevator gearing for each configuration and if he found it necessary to change it, to give his reasons.

3.1.3.1 Evaluations With A Target Airplane

In the interest of flight safety, the evaluations in which a second airplane was involved were conducted in a pre-planned and strictly controlled manner. During the early evaluation flights, the target airplane was a USAF F-100, but for most of the evaluations, the target airplane was an Air National Guard T-33.

All flights were operated in a specified airspace between specified altitudes as designated by the cognizant Air Route Traffic Control Center (ARTCC). Before beginning the evaluations, arrangements for airspace use were coordinated with the ARTCC, and during the flights day-to-day and flight-to-flight coordination was maintained. The pilot of the target airplane and the evaluation and safety pilots of the NT-33A were briefed prior to each flight. Standard procedures, including the evaluation maneuvers, were established and followed. The target airplane procedures and the evaluation airplane procedures were outlined on flight cards for ready in-flight reference. The pilots' flight cards for these procedures are presented below:

TARGET AIRPLANE PROCEDURES

1. Take off from Niagara Falls Airport and rendezvous with NT-33A UHF 257.0.
2. If no visual contact, proceed to control point (Grant intersection) and hold at 12,000 ft or as instructed by ARTCC.
3. Join up on NT-33A until NT-33A Evaluation Pilot is ready to begin tracking. Then NT-33A will assume a perch position.
4. When being acquired and tracked by NT-33A, perform following maneuvers:

   a. Steep turns, 60° bank angle sustained for short time. Then reverse to 60° bank turn in opposite direction and sustain for 1 minute or more.

b. Steep turns as above accompanied by altitude changes.

c. Symmetrical pull-up and pushover.

d. Repeat "a" (NT-33A disturbance inputs).

e. Random defensive maneuvers.

5. Join up in loose formation on the NT-33A.

6. Maintain position until second evaluation commences.

7. When evaluations complete, recover at Niagara Falls Airport.

NT-33A PILOT EVALUATION TASKS AND PROCEDURES WITH TARGET AIRPLANE

1. Take off from Buffalo International Airport and rendezvous with target aircraft UHF 257.0.

2. If no visual contact, proceed to control point (Grant intersection) and hold at 13,000 ft, or as instructed by ARTCC.

3. Enroute to control point, or after rendezvous, with target aircraft in wing position, perform the following:

   a. Obtain the specified calibration records.

   b. Small maneuvers about level flight, or other maneuvers as desired, for configuration familiarization.

   c. Check ability to trim and acceptability of elevator gearing.

4. Assume perch position on target aircraft. Acquire tracking position and begin tracking exercise.

5. Track target aircraft while he performs prescribed maneuvering.

6. Track target aircraft with disturbance inputs to NT-33A.

7. Track target aircraft in random maneuvering.

8. Assume lead position, comment, give ratings, and prepare for next evaluation or recovery at Buffalo.

These tasks were performed consecutively for each evaluation. The evaluation pilot could make comments at any time on a voice tape recorder.

3.1.3.2 Evaluations Without A Target Airplane

As mentioned above, evaluations without a target airplane were performed as prescribed in Reference 1, except that the brief look at ground attack capability was omitted.

A copy of the pilot flight card outlining the piloting task to evaluate each configuration is presented below:

PILOT EVALUATION TASKS WITHOUT
TARGET AIRCRAFT

<u>VFR (Bulk of Evaluation)</u>

1. Obtain the specified calibration records.

2. Trimmability - ability to stabilize and trim.

3. Pitch attitude tracking - ability to rapidly acquire and track distant air or ground targets.

4. Symmetric pull-ups and pushovers - ability to rapidly acquire and maintain a given load factor.

5. Horizontal maneuvering
   a) roll into 60° bank and maintain altitude - reverse
   b) rapid descending turns (90° bank) - reverse
6. Disturbance inputs - briefly check above in presence of disturbances.

<u>IFR (Brief Look)</u>

1. Trimmability.
2. Discrete error tracking task (record 1 minute).
3. Random noise tracking task (record 1 minute).
4. Symmetric pull-ups and pushovers - ability to rapidly acquire and maintain a given load factor.
5. Level turns - roll into 60° bank and maintain altitude - reverse.
6. Briefly check above in presence of disturbance inputs.

The evaluation pilot performed these tasks consecutively, making comments as he desired on a voice tape recorder. The discrete error and random error tracking tasks are discussed in Section 3.2.7, and the random disturbance inputs are discussed in Section 3.2.6.

3.1.3.3 Evaluations in the Aerial Refueling Task

The in-flight refueling task was accomplished with a U.S. Navy KA-3 tanker aircraft. Procedures for the refueling were established and followed with both airplanes under the control of the cognizant ARTCC. Before each evaluation flight, a thorough briefing was conducted with both the tanker and the NT-33A crews, and an airspace block was coordinated with the ARTTC.

The number of hook-ups, or attempted hook-ups, for any given evaluation was not specified, and was at the discretion of the evaluation pilot. Essentially, standard in-flight refueling procedures were followed, but briefly each evaluation progressed as follows:

1. After rendezvous with the KA-3 the NT-33A, receiver, would maintain a trail position, about 1/4 mile, and obtain the necessary calibration records.

2. When cleared by the tanker pilot, the receiver would advance to the pre-contact position and stabilize.

3. The evaluation pilot would perform hook-ups as necessary for evaluation.

4. After completion of the first evaluation, the receiver would back off to a 1/4 mile trail position to record pilot comments and ratings.

This procedure was followed until all scheduled evaluations were accomplished. Figure 6 shows the NT-33A in a refueling hook-up with the KA-3.

3.1.4 Pilot Comment and Rating Data

Pilot comments and ratings were the primary data obtained. The pilot rating can only be properly interpreted and objections properly assessed if good comments are obtained. Pilot comments were encouraged whenever the pilot thought it appropriate during the evaluation. For data consistency, it was required that the pilot comment on a prescribed listing of items at the completion of each evaluation. For the ACM/tracking task with a target airplane and for the aerial refueling task, the pilot was asked to make recorded comments on the items listed on the following Pilot Comment Card.

Figure 6 IN-FLIGHT REFUELING HOOK-UP OF NT-33A WITH KA-3 TANKER

PILOT COMMENT CARD
ACM WITH TARGET AND AERIAL REFUELING

Specific Comments

1. Ability to trim.

2. Are stick forces satisfactory?

3. Is stick motion satisfactory?

   a. Is reselection of elevator gearing necessary? Why?

   b. Describe compromises in reselection of elevator gearing.

4. Predictability of airplane response to pilot inputs (initial versus final response.)

5. Pitch attitude control:

   a. During refueling.

   b. During ACM.

6. Tracking capability during ACM.

7. Normal acceleration control.

8. Altitude control relative to tanker aircraft.

9. Longitudinal control in turns.

   a. During refueling.

   b. During ACM.

10. Effects of turbulence and random disturbance inputs. (not applicable to aerial refueling task).

11. Was lateral-directional control satisfactory? Did it detract from the longitudinal evaluation?

Summary Comments

1. Good features.
2. Objectionable features.
3. Special piloting techniques.
4. Pilot rating and PIO rating based on mission task.
5. Give primary reasons for ratings.

Several items on the card ask for comments for both ACM and refueling but any given evaluation applied only to one task or the other. Therefore, the pilot was requested to use the pilot comment card as it pertained to the particular evaluation and respond only to the applicable items.

For the ACM/tracking task without a target aircraft, the pilot comment card used in the study of Reference 1 was used in this experiment. The listing of items on the pilot comment card is reproduced below.

PILOT COMMENT CARD
WITHOUT A TARGET AIRCRAFT

Specific Comments

1. Ability to trim.
2. Stick forces O.K.?
   a. Any second thoughts on gearing selection?
3. Stick motions O.K.?
4. Predictability of airplane response to pilot inputs (initial vs. final response).
5. Pitch attitude control and tracking capability.
6. Normal acceleration control.
7. Longitudinal control in steep turns.
8. Effects of random disturbance inputs.

9. Any IFR problems which didn't show up VFR?

10. Lateral-directional control satisfactory?
    Did it detract from longitudinal evaluation?

Summary Comments

1. Good features.
2. Objectionable features.
3. Special piloting techniques.
4. Pilot rating and PIO rating.
    a. Record decision-making process
    b. Identify deficiency(ies) which most influenced each ratings.

At the end of each evaluation and after recording the appropriate comments, an overall pilot rating was assigned by the pilot to each configuration in accordance with the Cooper-Harper rating scale which is established and described in Reference 5 and shown in Figure 7. The pilot rating assigned by the evaluation pilot to each configuration included the effects that random noise disturbances and/or natural turbulence may have had on the overall handling qualities. The effect resulting from any tendencies toward pilot-induced oscillations (PIO) was also included in the overall pilot rating.

As shown by the pilot comment cards, the pilot was also asked to assign a PIO tendency rating to each configuration. This rating was based on the six point scale established in Reference 2 and shown on Figure 8. The PIO rating indicates the tendency of the airplane to oscillate during performance of the task maneuvers. The scale spans the complete range from "no tendency to induce undesirable motions" to divergent oscillations. As in the study of Reference 1, the PIO data from this experiment show strong correlation with the pilot rating data.

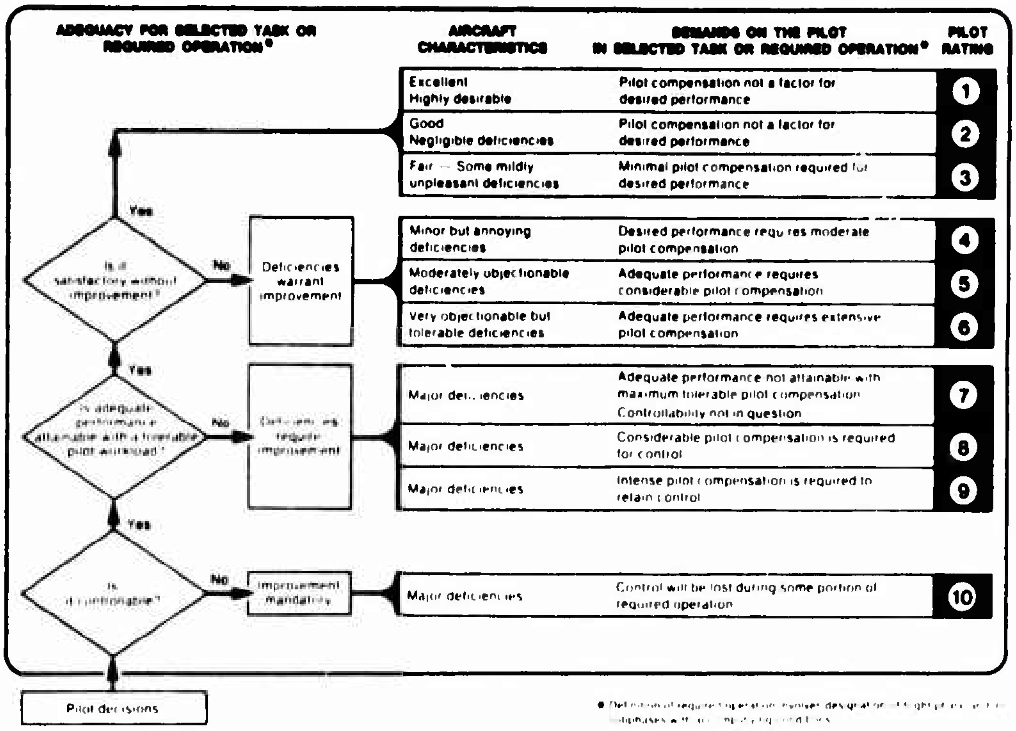

Figure 7 COOPER-HARPER HANDLING QUALITIES RATING SCALE

DESCRIPTION	NUMERICAL RATING
NO TENDENCY FOR PILOT TO INDUCE UNDESIRABLE MOTIONS	1
UNDESIRABLE MOTIONS TEND TO OCCUR WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. THESE MOTIONS CAN BE PREVENTED OR ELIMINATED BY PILOT TECHNIQUE.	2
UNDESIRABLE MOTIONS EASILY INDUCED WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. THESE MOTIONS CAN BE PREVENTED OR ELIMINATED BUT ONLY AT SACRIFICE TO TASK PERFORMANCE OR THROUGH CONSIDERABLE PILOT ATTENTION AND EFFORT.	3
OSCILLATIONS TEND TO DEVELOP WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. PILOT MUST REDUCE GAIN OR ABANDON TASK TO RECOVER.	4
DIVERGENT OSCILLATIONS TEND TO DEVELOP WHEN PILOT INITIATES ABRUPT MANEUVERS OR ATTEMPTS TIGHT CONTROL. PILOT MUST OPEN LOOP BY RELEASING OR FREEZING THE STICK.	5
DISTURBANCE OR NORMAL PILOT CONTROL MAY CAUSE DIVERGENT OSCILLATION. PILOT MUST OPEN CONTROL LOOP BY RELEASING OR FREEZING THE STICK.	6

Figure 8 PIO TENDENCY RATING SCALE

Except for the aerial refueling evaluations, the alphabetical turbulence effect rating assigned was solely an assessment of the effects on the handling qualities of random noise disturbances "injected" through the NT-33A variable stability system or the effects of any natural turbulence encountered. These ratings were established in accordance with the turbulence effect rating scale shown in Figure 9. The random disturbance inputs to the NT-33A variable stability system were not used during the aerial refueling evaluations. Normally both the tanker and the receiver aircraft, flying in rather close formation, would be subjected to essentially the same turbulence field. Since random disturbances could not be input to the tanker aircraft, the use of disturbances to the NT-33A would result in an unrealistic simulation situation in which only the receiver would be subjected to a "turbulence field" while the tanker continued to operate in smooth air. The impression derived from such a situation and the resulting turbulence effect rating, or for that matter the overall pilot rating, would likely not reflect adequately the effects of turbulence on the refueling task.

INCREASE OF PILOT EFFORT WITH TURBULENCE	DETERIORATION OF TASK PERFORMANCE WITH TURBULENCE	RATING
NO SIGNIFICANT INCREASE	NO SIGNIFICANT DETERIORATION	A
MORE EFFORT REQUIRED	NO SIGNIFICANT DETERIORATION	B
	MINOR	C
	MODERATE	D
BEST EFFORTS REQUIRED	MODERATE	E
	MAJOR (BUT EVALUATION TASKS CAN STILL BE ACCOMPLISHED)	F
	LARGE (SOME TASKS CANNOT BE PERFORMED)	G
UNABLE TO PERFORM TASKS		H

Figure 9 TURBULENCE EFFECT RATING SCALE

3.1.5 Data Acquisition

During the evaluations in ACM/tracking with a target airplane, motion pictures of the tracking portion of the task were taken through the NT-33A fixed reticle gun sight. Oscillograph and digital tape recordings were made simultaneously with the motion pictures; aircraft state variables and pilot control inputs were recorded. During the ACM/tracking evaluations without a target airplane, the evaluation pilot performed both discrete and random error tracking tasks during which pilot inputs, aircraft state variables, and tracking errors were recorded. Motion pictures and the recordings noted above were also obtained during the aerial refueling task evaluations. Pilot comments and ratings were recorded in flight, immediately following each evaluation, on a voice tape recorder for later transcription. As a backup, the safety pilot manually recorded the pilot ratings on the flight card which provided the variable stability gain settings for each configuration.

3.2 EQUIPMENT

Evaluations were conducted in the USAF three-axis variable stability NT-33A airplane, Figure 10, modified and operated by Calspan for the AFFDL, Air Force Systems Command. A complete description of the NT-33A airplane is contained in Reference 6.

In the NT-33A variable stability airplane, the system operator (who was also the safety pilot in the rear cockpit) altered the handling qualities about all three axes by varying the settings of the response-feedback gain controls. The evaluation pilot in the forward cockpit was unaware of the control surface motions resulting from the variable stability system signals since his controls moved only as a result of his own inputs. The front cockpit was equipped with a stick controller, which is representative of fighter airplanes. The instrument layout of the evaluation cockpit is shown in Figure 11.

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6. G.W. Hall and R.W. Huber, "System Description and Performance Data for the USAF/CAL Variable Stability T-33 Airplane," AFFDL-TR-70-71, June 1970.

Figure 10 USAF/CALSPAN VARIABLE STABILITY NT-33A

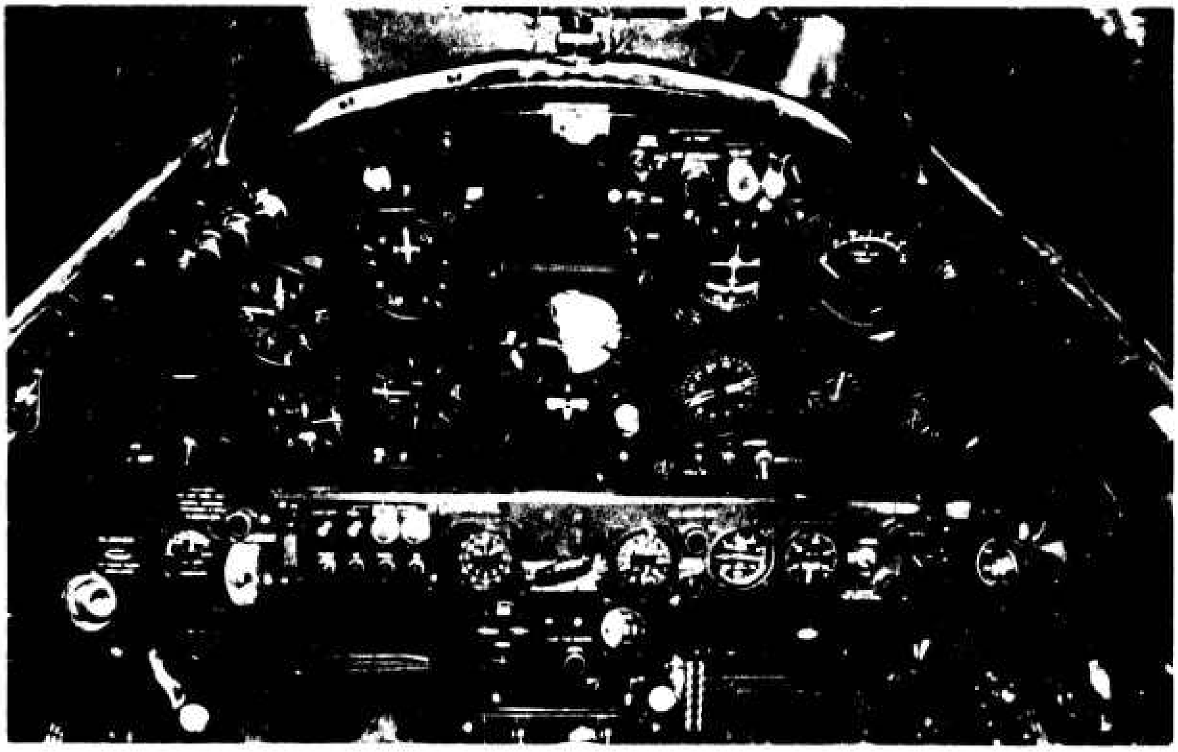


Figure 11 EVALUATION COCKPIT IN VARIABLE STABILITY NT-33A

3.2.1 Gun Sight and Camera

For evaluations in the ACM/tracking task with a target airplane, the NT-33A was fitted with a gun sight and a gun-sight-mounted camera, both shown in Figure 12. The gun sight was the Northrop Corporation noncompensated, depressible sight used in the A-37. The camera adapter for through-the-reticle viewing to record pipper excursions on the target was provided by the Flight Dynamics Laboratory. Motion pictures were taken through the gun sight at speeds of either four frames per second or 25 frames per second. The camera was mechanized to start operating automatically when the NT-33A digital tape recorder was turned on. Pipper tracking error may be determined from the motion pictures obtained. The camera was also used during the aerial refueling task to provide at least a qualitative assessment of the pilot's ease or difficulty in effecting an aerial refueling hook-up.

3.2.2 Refueling Probe

To perform actual refueling hook-ups, the NT-33A was fitted with a refueling probe from an F-100. The probe was reconfigured to be adapted to the NT-33A, as shown in Figure 13. The refueling probe was plugged at the lower end prohibiting any transfer of fuel during the evaluations. There were no modifications or alterations to the aircraft fuel system.

3.2.3 Feel System Characteristics

The feel system characteristics were held constant for all configurations evaluated in this experiment. The dynamics for the elevator stick feel system were as follows:

$$\omega_{fs} = 31 \text{ rad/sec}$$

$$\zeta_{fs} = 1.0$$

The elevator stick static force gradient was 22 lb/in. The elevator to control input gearing ratio was discussed in Section 3.1.3.

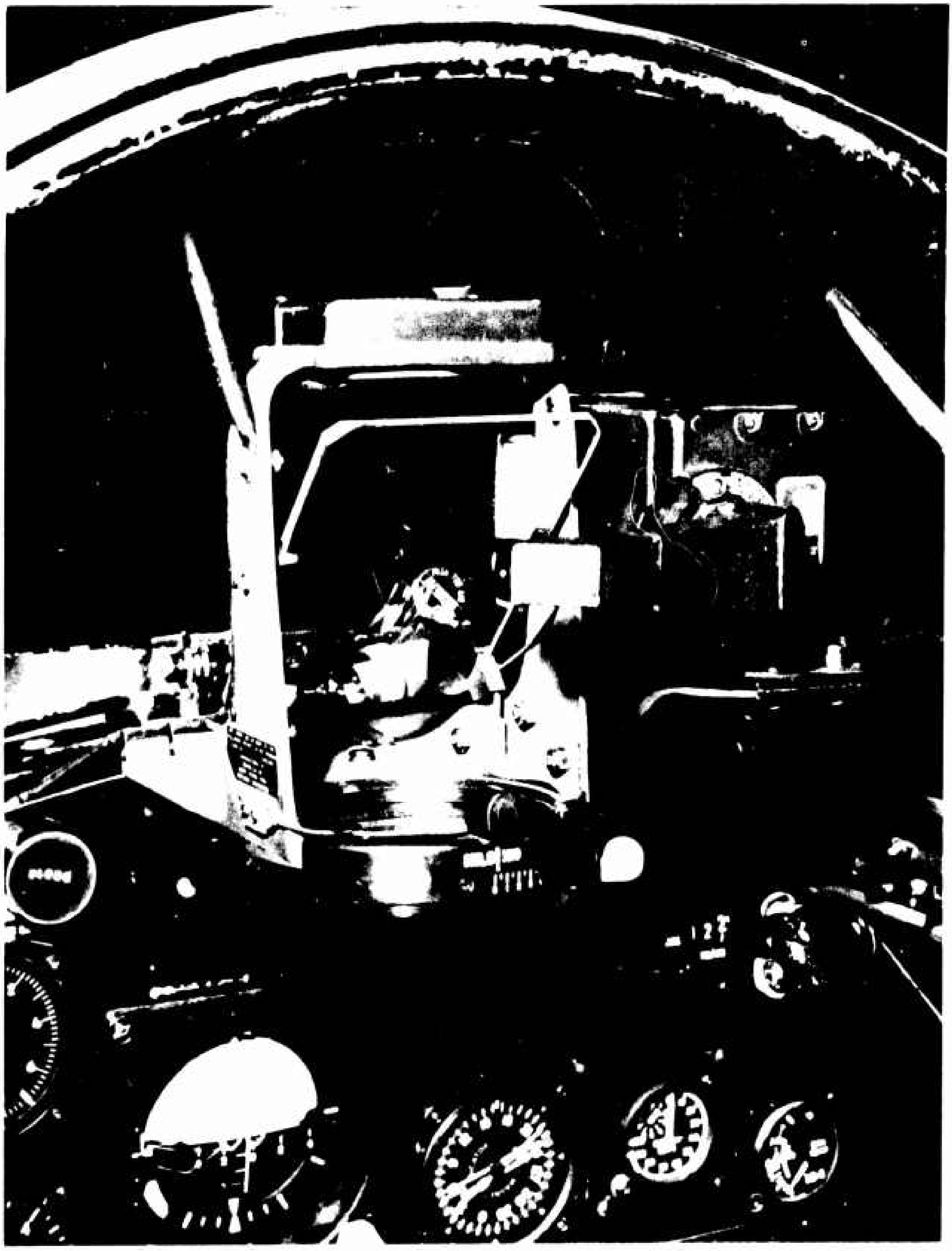


Figure 12 GUN SIGHT AND GUN-SIGHT-MOUNTED CAMERA

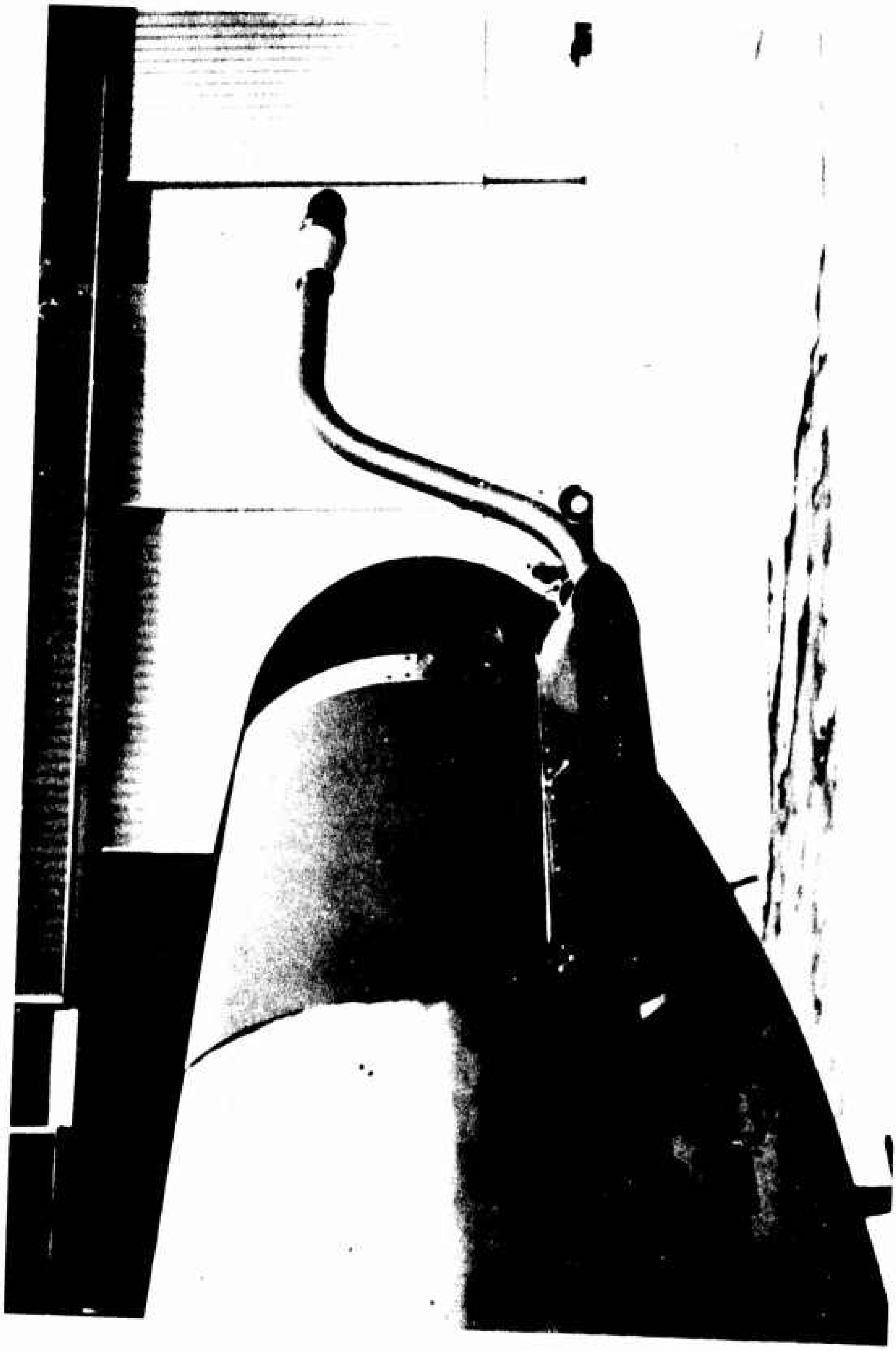


Figure 13 AERIAL REFUELING PROBE INSTALLATION

The aileron and rudder feel systems had the following frequency and damping ratio:

$$\omega_{f_S} = 25 \text{ rad/sec}$$

$$\zeta_{f_S} = 0.7$$

The aileron and rudder static force gradients were maintained at the following values:

$$F_{AS}/\delta_{AS} = 4 \text{ lb/in.}$$

$$F_{RP}/\delta_{RP} = 150 \text{ lb/in.}$$

The feel system force gradient in all three axes was linear.

3.2.4 Phugoid Characteristics

In this experiment, no attempt was made to control the phugoid characteristics; therefore, they were essentially those of the NT-33A airplane as shown below:

IAS	n/α (g/rad)	T_P (sec)	ζ_P
250	≈ 18.5	≈ 70	≈ 0.10
350	≈ 50.0	≈ 100	≈ 0.15

3.2.5 Lateral-Directional Characteristics

The lateral-directional characteristics used in this experiment were essentially those used in the study of Reference 1. In that study a "good" set of lateral-directional characteristics was selected for each flight condition. These characteristics were held fixed throughout the program, except for the variations due to changes in moments of inertia as fuel was consumed.

The approximate lateral-directional characteristics obtained from measurements of flight records are shown below:

$V_{ind} = 250$ kt $n/\alpha = 18.5$ g/rad	$V_{ind} = 350$ kt $n/\alpha = 50$ g/rad
$\omega_d \approx \omega_\phi \approx 2.2$ rad/sec $\zeta_d \approx \zeta_\phi \approx 0.20$ $\lvert\phi/\beta\rvert_d \approx 0.5$ $\tau_R \approx 0.3$ sec $\tau_S \approx 75$ sec	$\omega_d \approx \omega_\phi \approx 4.5$ rad/sec $\zeta_d \approx \zeta_\phi \approx 0.30$ $\lvert\phi/\beta\rvert_d \approx 0.5$ $\tau_R \approx 0.2$ sec $\tau_S \approx 75$ sec

3.2.6 Random Disturbance Inputs

In a fighter aircraft task, the turbulence encountered has a bearing on the ability of the pilot-airplane system to accomplish the mission. The NT-33A does not have the capability to vary the lift response to gust-induced angle-of-attack changes; therefore, the independent heaving motion normally associated with vertical gusts cannot be simulated. The lateral-directional responses to gust can be more realistically simulated since they primarily affect the angular accelerations of the airplane. Though not an exact simulation of turbulence, random noise sources were used to provide disturbances to the airplane during the evaluations by driving the NT-33A control surface actuators with filtered random Gaussian white noise signals.

Since the configurations evaluated in this experiment were the same as those evaluated in the study of Reference 1, the same random noise input gains were used to the NT-33A control surface actuators. The rationale for the selection of the level of the random noise signals is given in Reference 1. Although the level of the random noise was that used in the previous study, the character of the random inputs was changed somewhat. After the study of Reference 1 was performed, the random noise input circuits were modified. In the current study, four independent random noise sources were used in the system. Three of the noise generators provided uncorrelated signals to the ailerons, rudder and elevator servo actuators. Signals from a fourth noise source were passed through a level sensing circuit which switched out all noise signals to the surface actuators when the signal dropped below a predetermined level. In this way it was possible to simulate the "patchiness" of real turbulence.

The evaluation pilots were made aware that the airplane's response to the random noise inputs was only an approximation to the response to real turbulence.

3.2.7 The IFR Programmed Tracking Tasks

Two pitch attitude tracking tasks, discrete and random, were included in the IFR portion of the evaluations without a target airplane to aid the pilot in his evaluation. These tasks were included in the current study to duplicate, as nearly as possible, the evaluations performed in the study of Reference 1. These tasks were representative, in pitch attitude tracking, of the air-to-air intercept tracking task, where radar steering information is normally displayed to the pilot. In this experiment, the center instrument shown in Figure 11 (a Lear remote attitude director indicator), was programmed so that the horizontal command bar displayed pitch attitude command tracking error during the tracking tasks - that is, the error between the commanded pitch attitude and the airplane pitch attitude. When the airplane pitch attitude matched the commanded pitch attitude, the command bar was centered.

A complete cycle of the discrete error pitch attitude command signal is shown in Figure 14. The repetition period was long enough, for the brief pitch attitude tracking task, to prevent the pilot from anticipating the direction, magnitude, or rapidity of the commands. A commanded pitch attitude of $\pm$ 5 degrees represented full scale ($\pm$ 1 inch) deflection of the horizontal command needle. The evaluation pilot's task of minimizing the error required rapid and precise changes in pitch attitude. After a brief practice period for the pilot to investigate techniques for tracking, a short recording of his tracking performance was made.

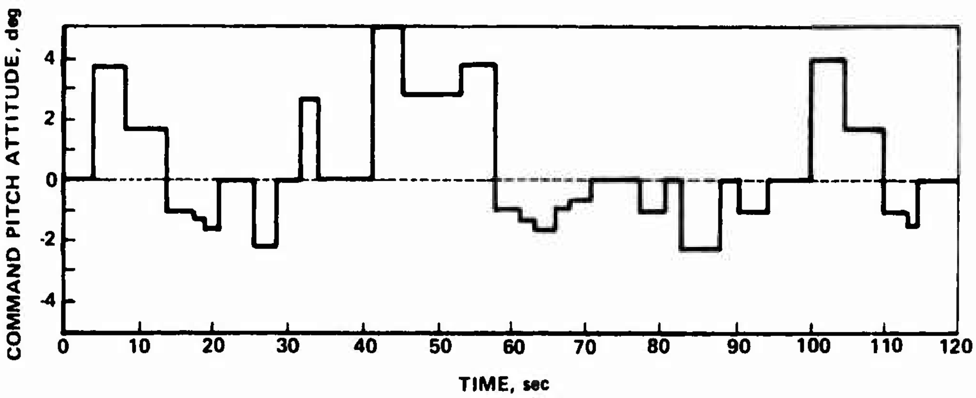


Figure 14 DISCRETE ERROR TRACKING TASK

The random error pitch attitude tracking task was implemented by displaying the error between the actual pitch attitude and the pitch attitude commanded by a filtered random noise signal. A sample of the random pitch attitude commands is shown in Figure 15.

This task required the pilot to continuously maneuver the airplane to minimize the error. Short records of this task were also made after the pilot had practiced the task for a brief period.

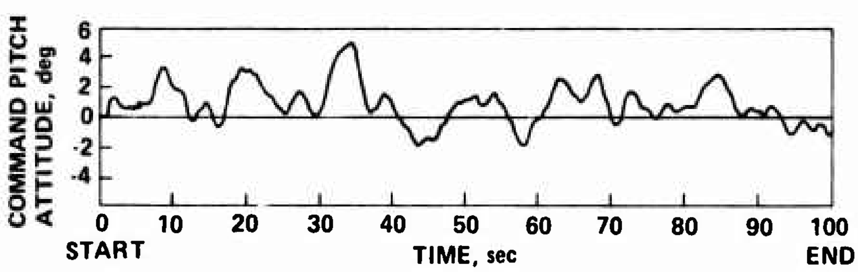


Figure 15 RANDOM ERROR PITCH ATTITUDE COMMAND SIGNAL

Section IV
RESULTS OF PHASE I EXPERIMENT

The purpose of the Phase I experiment was to provide data from which to determine the effect of the evaluation technique and the effect of the evaluation task on the handling qualities assessment. The evaluation technique was investigated by re-evaluating selected configurations of Reference 1 in a mock ACM/tracking situation with a "target airplane." Some of the configurations of Reference 1 were also re-evaluated using the technique that was used previously, that is, without a target airplane. The effect of the evaluation task was investigated by evaluating selected configurations from the study of Reference 1 in the aerial refueling task.

Because of the different "tasks" and "techniques" used in the present experiment, the current results can be compared for evaluations with and without a target airplane in the ACM/tracking task. Also, the results of the aerial refueling evaluations can be compared with the results of the ACM/tracking evaluations. Of course, all the results of the present experiment can be compared to those obtained in the study of Reference 1. To facilitate the latter comparison, a summary of the Reference 1 pilot rating results is presented.

4.1 SUMMARY OF PILOT RATING RESULTS FROM AFFDL-TR-70-74 (REF. 1)

The data from the study of Reference 1, including pilot rating, PIO rating, and pilot selected F_s/n are shown in Tables I and II for the two pilots who participated in that investigation. For a more complete review of the pilot rating data and the associated pilot comments, the reader is referred to the referenced study. The data reproduced from Reference 1 provide the reader with a readily available set of data from the reference study to which the results of the present experiment can be compared.

Table I
SUMMARY OF EXPERIMENTAL RESULTS FROM AFFDL-TR-70-74 (PILOT M)

NUMBERS IN BLOCKS REFER TO THE FOLLOWING: CONFIGURATION NO. / FLIGHT NO./PR/PIOR/$\frac{F_s}{n}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS: n/α 18.5 g/rad, $1/T_{\theta_2}$ 1.25 sec^{-1}, V_T 480 ft/sec; ω_{sp}/ζ_{sp}					n/α 50 g/rad, $1/T_{\theta_2}$ 2.4 sec^{-1}, V_T 675 ft/sec; ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_3	ζ_3	[illegible]	4.9/0.70	9.7/0.63	5.0/0.28	5.1/0.18	3.4/0.67	7.3/0.73	16.5/0.69
0.5	2	63	0.75	1A 1032*/2/[illegible]/4.4 1065/6/2.5/7.2 1071/4/1.5/7.2							
0.8	3.3								6A 1033/5/2/8.9		
2	[illegible]			[illegible]	[illegible] [illegible]/4.5/2/5.9						
3.3	[illegible]								6B 1047/2.5/1.5/2.8 1075/1/1/5.4	7A 1046/5/2/3.7 1075/4/2/6.2	
5	12				2C 1044/3/1.5/4.6						
8	19	↓	↓							7B 1044/3/1.5/3.1	
∞	∞	75	0.67	1D 1028/5/2.5/9.0 1047/4.5/2/4.8	2D 102[illegible]/[illegible]/2/9.9 1045/2.5/1/3.[illegible]	3A 1023/5/3/10.8 1044/4/1.5/5.4	4A 1032/5.5/2.5/8.7	5A 1026/7/3/10.0	6C 1026/4/2.5/6.5	7C 1022/3/2/5.6 1053/3/2/3.9	8A 1028/5/2.5/6.3
	19	63	0.75							7D 1048/5.5/3/3.0	8B 1045/3.5/1.5/3.3
	12				2E 1045/4/1/3.8	3B 1048/4.5/2/4.3	4B ----	5B ----			
	8								6D 1039/5.5/2.5/4.9	7E 1050/6/3/5.1	8C 1035/3.5/2/5.7
	5			1E 1035/6/3.5/9.0	2F 1039/3/[illegible]/5.5	3C 1035/4/2/7.2	4C 1047/8.5/4/3.9	5C 1039/9/5/7.3			
	3.3								6E 1040*/5.5/2.5/3.2 107[illegible]/8.5/5/5.7	7F 1032/3/2/5.6 1057/4/2/4.5 1065/4/2/4.9	8D 1058/2/1/5.5
	2			1F 10[illegible]/8/4/[illegible]	2H 1022/5/2.5/8.2 1040/6/2.5/4.9	3D 1058/4/2/5.1	4D 1040/8/3.5/3.9 105[illegible]/9/5/5.9	5D 1033/8.5/4/11.0 1057/9/5/5.4		7G 1058/5/2/4.9	
	0.8								6F 1030*/6/2.5/7.8 1070/8/4/6.7	7H ----	8E 1063/2.5/1/4.6 1070/3/1/4.6
↓	0.5	↓	↓	1G 1030/8.5/4.5/6.0	2J 1063/6/2/5.5	3E 1063/4/1.5/4.8	4E 1052/7.5/4/3.9	5E 1030/8/4/6.3			
2	5	16	0.75	1C 1036*/2/1/8.0 1054/5/2.5/7.2 1066/3.5/2/9.0	2B 1036*/2.5/1.5/5.4 1054/6/2.5/6.0 1066/6/3/6.6						
∞	5				2G 1053/7/3/5.5						
↓	2	↓	↓		2I 1036/8/4.5/4.6						

SIX ADDITIONAL CONFIGURATIONS: STICK POSITION COMMANDS USED (SEE SECTION 2.1)

$1/\tau_1$	$1/\tau_2$	ω_3	ζ_3	ω_{sp}/ζ_{sp}				ω_{sp}/ζ_{sp}		
∞	∞	75	0.67	2.3/1.7	2.3/1.2	3.3/1.1		10/0.45	13/0.34	15.6/0.23
↓	↓	↓	↓	9 1070/6/2/9.7	10 1075/4/1.5/8.2	11 1065/3/1/7.8		12 1052/5/2.5/4.9 1071/6/2.5/8.4	13 1053/7/3/6.0 1066/5.5/2.5/8.1	14 1052/4.5/2/5.4 1054/6/3/5.4

*THESE RATINGS NOT USED IN DATA ANALYSIS (SEE DISCUSSION IN APPENDIX I OF REF. 1)

Table II
SUMMARY OF EXPERIMENTAL RESULTS FROM AFFDL-TR-70-74 (PILOT W)

NUMBERS IN BLOCKS REFER TO THE FOLLOWING: CONFIGURATION NO. / FLIGHT NO./PR/PIOR/$\frac{F_s}{n}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS: n/α = 18.5 g/rad, $1/T_{\theta_2}$ = 1.25 sec^{-1}, V_T = 480 ft/sec; ω_{SP}/ζ_{SP}					n/α = 50 g/rad, $1/T_{\theta_2}$ = 2.4 sec^{-1}, V_T = 675 ft/sec; ω_{SP}/ζ_{SP}		
$1/T_1$	$1/T_2$	ω_3	ζ_3	2.2/0.69	4.9/0.70	9.7/0.63	5.0/0.28	5.1/0.18	3.4/0.67	7.3/0.73	16.5/0.69
0.5	2	63	0.75	1A 1043*/2/1/6.0 1073/5/2/7.2							
0.8	3.3								6A 1034/6/3/3.5		
2	5			1B 1074/3/1.5/6.5	2A 1051/4/2/5.1						
3.3	8								6B 1074/4/1.5/5.4	7A 1074/2/1/4.7	
[illegible]	12				2C						
8	19	↓	↓							7B ———	
∞	∞	75	0.67	1D 1043/3/1/4.2 1067/4/2/6.0	2D 1031/2.5/1/5.9	3A 1024/4/1/11.5 1072/4/1.5/5.7	4A 1041/5/2/5.3	5A 1029/5/1.5/6.3 1051/6/3/5.5	6C 1029*/2.5/1/3.9 1072/5/2/5.4	7C 1027/4/1/3.2 1062/1.5/1/4.7	8A 1041/4/1/4.0
	19	61	0.75							7D ———	8B ———
	12				2E ———	3B	4B 1062/7/4/5.6	5B 1062/7/4/7.1			
	8								6D ———	7E 1056/5/2/3.5	8C 1051/3/1/3.9
	5			1E ———	2F ———	3C 1056/3/1/5.1	4C ———	5C 1056/7/4/7.3			
	3.3								6E 1073/7/4/5.4	7F 1024/7/-/5.0 1043/7/3.5/3.2 1064/7/4/4.7	8D 1064/4/2/4.6
	2			1F 1034/8/4/6.0	2H 1027/5.5/2/5.7	3D 1059/4/1/5.4	4D ———	5D 1034/9/4/7.3		7G 1059/6/2/4.9	
	0.8								6F 1031/8.5/4/3.0 1067/10/5/5.4	7H 1061/5/2/4.7	8E 1067/5/2/4.6
↓	0.5	↓	↓	1G 1061/8.5/4/4.6	2J 1060/6/2/4.9	3E 1061/4/1/4.5	4E ———	5E 1041/8/4/4.4			
2	5	16	0.75	1C 1038/4/1.5/8.0	2B 1038/4/1.5/4.9 1072/5/2.5/5.9						
[illegible]	5				2G ———						
↓	[illegible]	↓	↓		2I 1038/8/4/4.9						

SIX ADDITIONAL CONFIGURATIONS: STICK POSITION COMMANDS USED

$1/T_1$	$1/T_2$	ω_3	ζ_3	ω_{SP}/ζ_{SP}
∞	∞	75	0.67	10/0.45
↓	↓	↓	↓	12 1073/6/3/8.3

*THESE RATINGS NOT USED IN DATA ANALYSIS (SEE DISCUSSION IN APPENDIX I OF REF. 1)

4.2 RESULTS FROM THE CURRENT INVESTIGATION (PHASE 1)

Tables III through VII show the pilot rating results obtained in the present experiment. These tables present the results in order as follows:

Table III - ACM Task With Target (Pilot A)

Table IV - ACM Task Without Target (Pilot A)

Table V - ACM Task With Target (Pilot B)

Table VI - ACM Task Without Target (Pilot B)

Table VII - Aerial Refueling (Pilot A)

The pilot rating results in the above tables are presented in essentially the same format as the above results from Reference 1. The flight numbers are not shown on the tabular results, but the evaluation flight numbers, which began with "Evaluation Flight 1" and proceeded in sequence throughout the experiment, are shown in the pilot comment summaries in Appendix I. The turbulence effect ratings also are not included on the tabular results but are shown on the pilot comment summaries. When it is noted that the turbulence response, or the response to random disturbance inputs was a significant factor in the pilot rating obtained, then the turbulence response and its effect will be discussed. The PIO rating and the values of F_s/n assigned, or obtained, in the present experiment are also shown on the above tables. The complete summary of pilot comments for the configurations evaluated in this experiment, presented in Appendix I, are grouped by configuration and ordered in sequence for evaluations with target, without target and aerial refueling.

Bode plots and time histories for each configuration are presented in Appendix I of Reference 1 and the reader is referred to the reference study for this information. The short-period characteristics obtained in the current experiment were not exactly the same as those obtained in the referenced study; however, for most cases the differences were small. The short-period frequencies in the current experiment were within ten percent or less of the values obtained

Table III

ACM TASK WITH TARGET (PILOT A)

Numbers in Blocks Refer to the Following: Configuration No. PR/PIOR/$\frac{S}{W}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS							
				$n/\alpha \approx 18.5$ g/rad $1/T_{\theta_2} = 1.25$ sec^{-1}					$n/\alpha \approx 50$ g/rad $1/T_{\theta_2} = 2.4$ sec^{-1}		
				ω_{sp} / ζ_{sp}					ω_{sp} / ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.2/0.70	4.5/0.72	9.5/0.63	4.5/0.29	4.7/0.18	3.0/0.68	7.3/0.85	16.0/0.73
2	5	63	0.75	1B 4/2/5.0	2A 4/2/5.6						
3.3	8								6B 5/2/4.6		
5	12				2C 4.5/2/5.0						
∞	∞	75	0.67	1D 3/1/5 8	2D 3/1/6.5 2.5/1/6.5	3A 7/4/5.7	4A 4/2/6.1	5A 6/3.5/6.7	6C 8/3/4.6 7.5/2/4.6	7C 2.5/1/4.7	8A 6/3/4.7
	19	63	0.75								8B 7/4/3.8
	12				2E 7/4/4.2 6/4/4.2						
	8								6D 8/4/4.1		
	5			1E 8/3/8.7	2F 7/4/6.0						
	3.3									7F 7/4/4.7	8D 2/1/4.7
	2				2H 4/1.5/6.3	3D 6/3/5.4	4D 8/4/6.9				
	0.5				2J 5/2/5.4			5E 8/4/7.6			

SIX ADDITIONAL CONFIGURATIONS: STICK POSITION COMMANDS USED

				ω_{sp} / ζ_{sp}					ω_{sp} / ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.3/1.7	2.3/1.1	3.2/1.1			10.0/0.44	15.0/0.30	16.0/0.21
∞	∞	75	0.67	9 6/1/8.2	10 3/1/6.2	11 2.5/1/12.0			12 2/1/5.3 3/1.5/5.3	13 2/1/5.8 2/1/5.8	14 8/4/5.8

Table IV
ACM TASK WITHOUT TARGET (PILOT A)

Numbers in Block Refer to tne Following:

Configuration No.
PR/PIOR/$\frac{F_s}{n}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS							
				$n/\alpha \approx 18.5$ g/rad, $1/T_{\theta_2} = 1.25\ sec^{-1}$					$n/\alpha \approx 50$ g/rad, $1/T_{\theta_2} = 2.4\ sec^{-1}$		
				ω_{sp}/ζ_{sp}					ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.2/0.70	4.5/0.72	9.5/0.63	4.5/0.29	4.7/0.18	3.0/0.68	7.3/0.85	16.0/0.73
2	5	63	0.75	1B 7/1/5.0	2A 3/1.5/5.6						
3.3	8	↓	↓						6B 3/1/4.6		
5	12	↓	↓		2C 3/1.5/5.0						
∞	∞	75	0.67		2D 3/1/6.5		4A 5/3/6.1		6C 6/2/4.6		
↓	19	63	0.75								8B 3/1/4.1
↓	8	↓	↓						6D 9/5/4.1		
↓	5	↓	↓	1E 8/3.5/8.7	2F 7/4/6.0						
↓	2	↓	↓				4D 9/5/6.9				
↓	0.5	↓	↓		2J 5/1.5/5.4			5E 9/4.5/7.6			

SIX ADDITIONAL CONFIGURATIONS: STICK POSITION COMMANDS USED

				ω_{sp}/ζ_{sp}			ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	3.2/1.1			10.0/0.44	15.0/0.30	16.0/0.21
∞	∞	75	0.67	11 4.5/1/12.0			12 7/3.5/5.3	13 7/4/5.8	14 7/3/5.8

Table V
ACM TASK WITH TARGET (PILOT B)

Numbers in Block Refer to the Following: Configuration No. PR/PIOR/$\frac{F_s}{n}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS							
				$n/\alpha \approx 18.5$ g/rad $1/T_{\theta_2} = 1.25$ sec^{-1}					$n/\alpha \approx 50$ g/rad $1/T_{\theta_2} = 2.4$ sec^{-1}		
				ω_{sp}/ζ_{sp}					ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.2/0.70	4.5/0.72	9.5/0.63	4.5/0.29	4.7/0.18	3.0/0.68	7.3/0.85	16.0/0.73
2	5	63	0.75	1B 5/3/5.0							
3.3	8								6B 7/4/4.6		
∞	∞	75	0.67	1D 3/1/5.8	2D 2/1/6.5						
	3.3	63	0.75							7F 5/3/4.7	8D 2/1/4.7

Table VI
ACM TASK WITHOUT TARGET (PILOT B)

Numbers in Block Refer to the Following: Configuration No. PR/PIOR/$\frac{F_s}{n}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS							
				$n/\alpha \approx 18.5$ g/rad $1/T_{\theta_2} = 1.25$ sec^{-1}					$n/\alpha \approx 50$ g/rad $1/T_{\theta_2} = 2.4$ sec^{-1}		
				ω_{sp}/ζ_{sp}					ω_{sp}/ζ_{sp}		
$1/\tau_1$	$1/\tau_1$	ω_s	ζ_s	2.2/0.70	4.5/0.72	9.5/0.63	4.5/0.29	4.7/0.18	3.0/0.68	7.3/0.85	16.0/0.73
2	5	63	0.75	1B 6/4/5.0							
3.3	8								6B 6/3/4.6		
5	12				2C 4/2/5.0						
∞	∞	75	0.67	1D 4/2/5.8	2D 2/1/6.5						

Table VII
AERIAL REFUELING TASK (PILOT A)

Numbers in Block Refer to the Following: Configuration No. PR/PIOR/$\frac{F_s}{n}$

CONTROL SYSTEM CHARACTERISTICS				SHORT PERIOD CHARACTERISTICS $n/\alpha \approx 18.5$ g/rad $1/T_{\theta_2} = 1.25\ \text{sec}^{-1}$ ω_{sp} / ζ_{sp}				
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.2/0.70	4.5/0.72	9.5/0.63	4.5/0.29	4.7/0.18
2	5	63	0.75	1B 1/1/5.8	2A 2.5/1/5.6			
∞	∞			1D 4.5/2/5.8 4/1.5/5.8 2/1/5.8	2D 1/1/6.5 1/1/6.5 2/1/6.5		4A 3/1/6.1 4.5/2/6.1	5A 4/2/6.7 6/2/6.7 5/2/6.7
	5			1E 10/5/8.7				
	2						4D 4/2/11.1	5D 8/4/8.9
	0.5				2J 8/4.5/5.4			5E 9/5/7.6

SIX ADDITIONAL CONFIGURATIONS: STICK POSITION COMMANDS USED

				ω_{sp} / ζ_{sp}		
$1/\tau_1$	$1/\tau_2$	ω_s	ζ_s	2.3/1.7	2.3/1.1	3.3/1
∞	∞	75	0.67	9 5/2/8.2 6/2/8.2 5/2/8.2	10 6/3/6.2 4/1.5/6.2	11 2.5/1/12.0

in referenced study except for Configuration 6 and Configuration 13, which were within fifteen percent of the values given in Reference 1. The maximum difference between the damping ratios of the current study and the referenced study was less than fifteen percent, generally being about five percent. The control system characteristics, obtained from networks on electronic circuit cards, were essentially identical to those of the referenced study.

The applicable longitudinal equations of motion, transfer functions and details of the simulation mechanization in the NT-33A airplane are presented in Appendices IV and V of Reference 1 and therefore will not be presented in this report.

4.3 COMPARISON OF PILOT RATING RESULTS

In comparing pilot rating results, it is natural to point out those cases for which a significant difference is in evidence, but this implies having established a criterion or definition for a significant difference. Once the criterion or definition is established, then the results can be divided into two general categories; those for which the significant difference exists between the pilot ratings for a different evaluation technique or task, and those for which there is not significant difference. The configurations in the latter category can then be practically omitted from further discussion since the evaluation task difference or evaluation technique difference would have had no effect on the results obtained and a conclusion to that effect can be stated. For those configurations in the former category; that is, a significant difference in pilot rating results with differing evaluation task or technique, the reason for the difference must be investigated. Before proceeding with a criterion for a significant difference the word "significant" must be defined.

In Reference 7 it was shown that the standard deviation of pilot ratings varied between values of one and two depending upon the mean value of the pilot rating. The larger variation occurred for a mean pilot rating of 4.3. However, the quantity of data obtained in a handling qualities experiment, particularly for any single configuration, is usually too limited to lend itself to a statistical analysis, and that is the case in both the present experiment and the study of Reference 1. Therefore, the word "significant" as used here has no statistical implications. It simply means "important" or "of consequence".

4.3.1 Intra-Pilot Rating Variation

Figures 16 through 19 show the intra-pilot variation in pilot rating for the data from Reference 1 and the data from the present experiment. The reader is reminded that Pilot W of the Reference 1 study was Pilot A of the present experiment. Since all the configurations evaluated in the present experiment were selected from those of Reference 1, then intra-pilot rating variations for Pilot W/Pilot A can be shown, as in Figures 17 and 18. It should be noted that Figures 16, 17 and 19 are symmetrical about the diagonal line of zero pilot rating variation. When plotting the repeat rating data in these figures, each pilot rating obtained for a given configuration was considered to be the independent variable once, and the other pilot ratings in the repeated set were plotted as dependent variables. For example, Configuration 1A was rated three times by Pilot M, Table I, with PR = 2, 6, and 4. Six points appear in Figure 16 for Configuration 1A. If PR = 2 is taken as independent, then plotted points appear at the PR coordinates 2, 6 and 2, 4 for the ordinate and abscissa, respectively. Taking PR = 6 as the independent

7. E.A. Kidd and G. Bull, "Handling Qualities Requirements as Influenced by Pilot Evaluation Time and Sample Size" CAL Report No. TB-1444-F-1 Contract No. NOW 60-0393-C, February 1962.

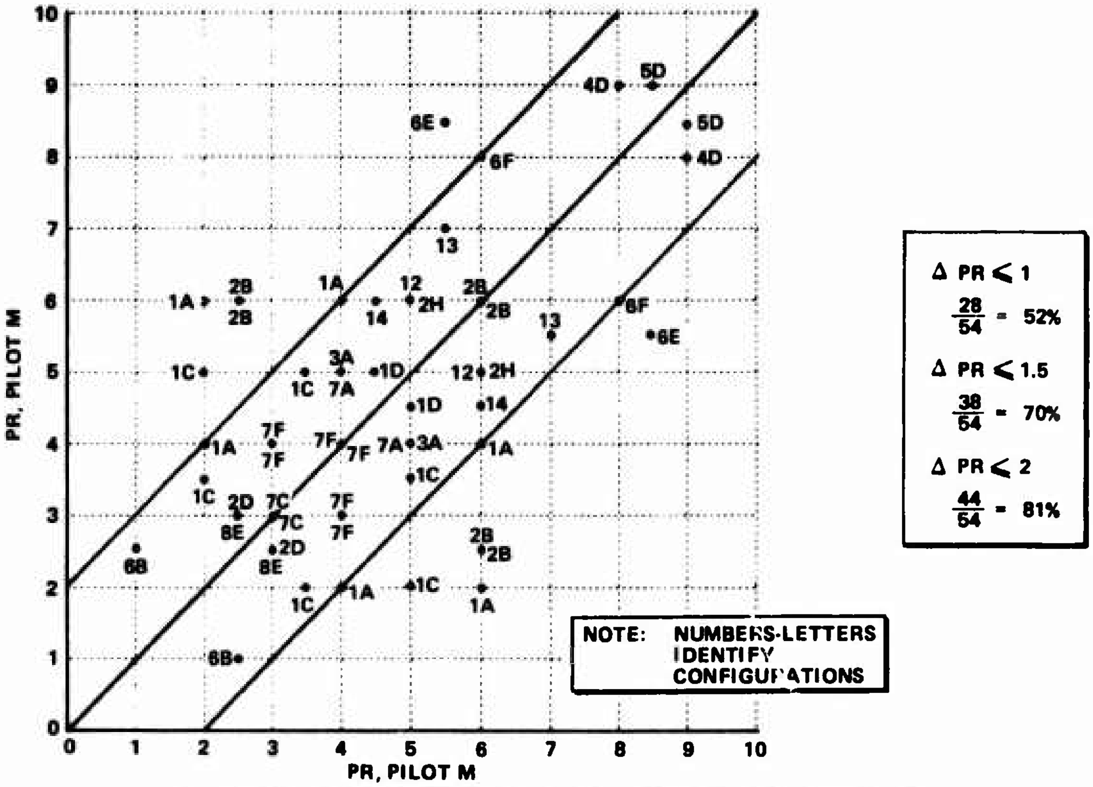


Figure 16 INTRA-PILOT RATING VARIATION, PILOT M

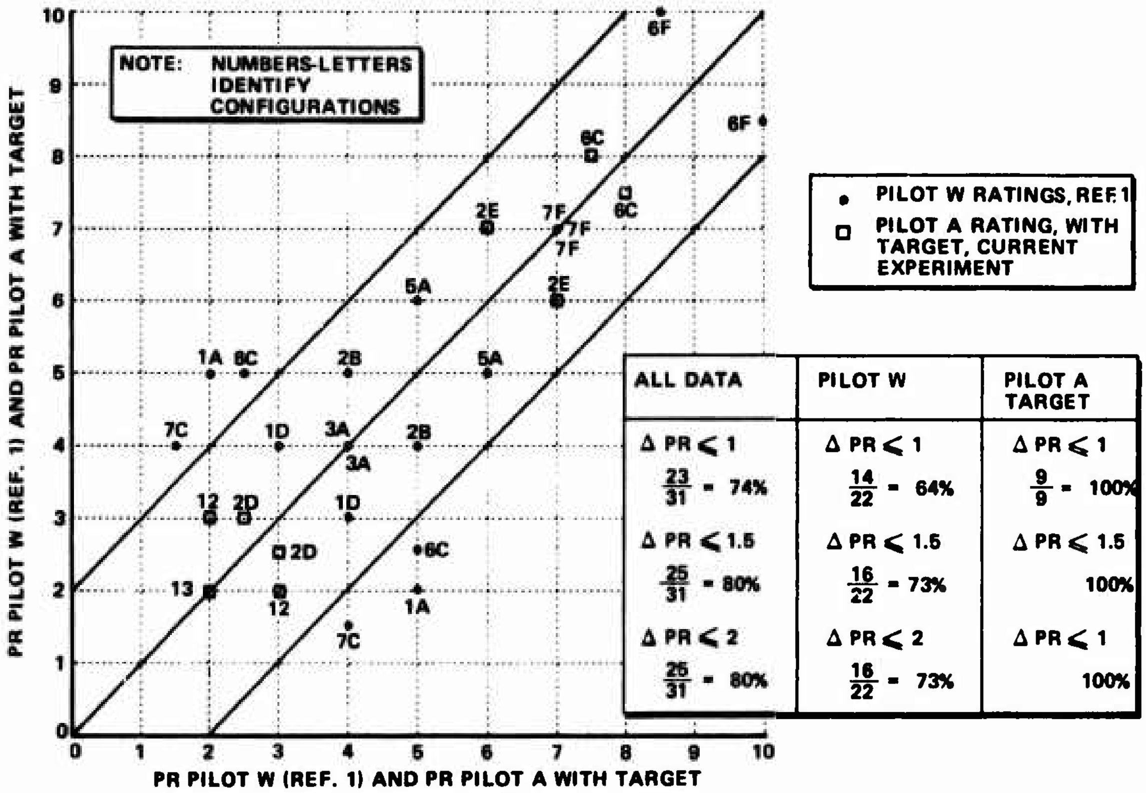


Figure 17 INTRA-PILOT RATING VARIATION, PILOT W (REF. 1), NO TARGET AND PILOT A, WITH TARGET

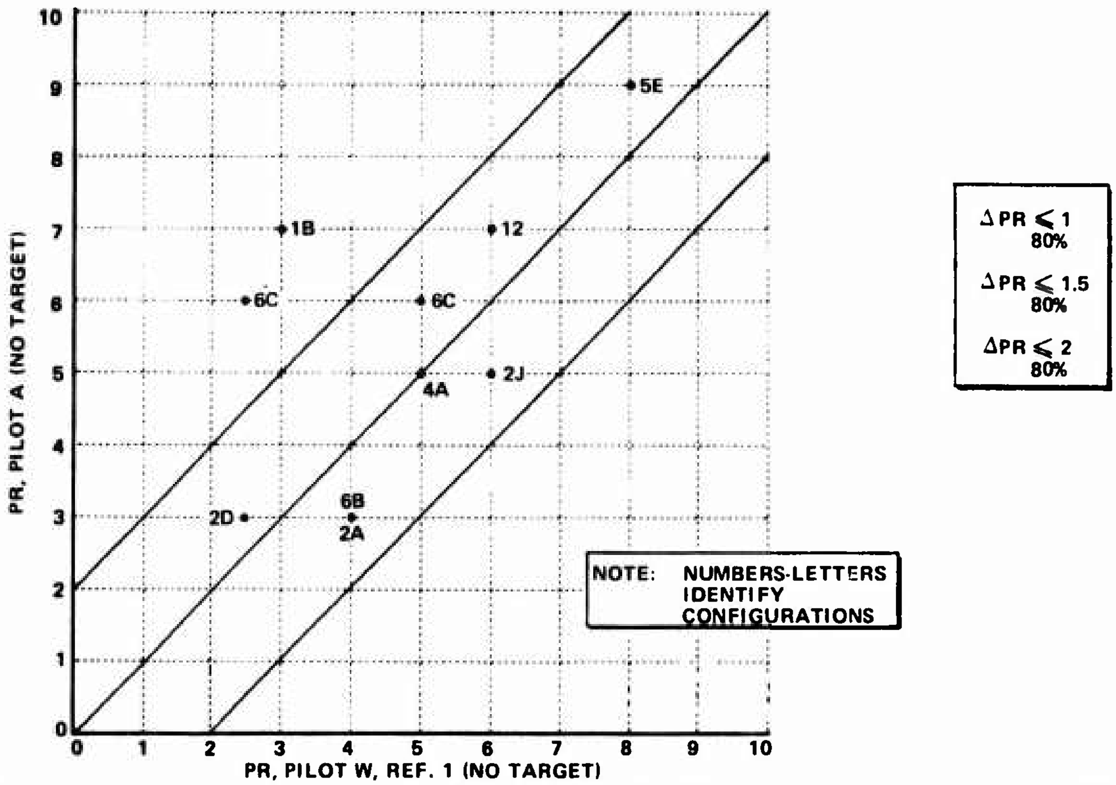


Figure 18 INTRA-PILOT RATING VARIATION FOR PILOT A, NO TARGET RATINGS, VS PILOT A RATINGS AS PILOT W (REF. 1)

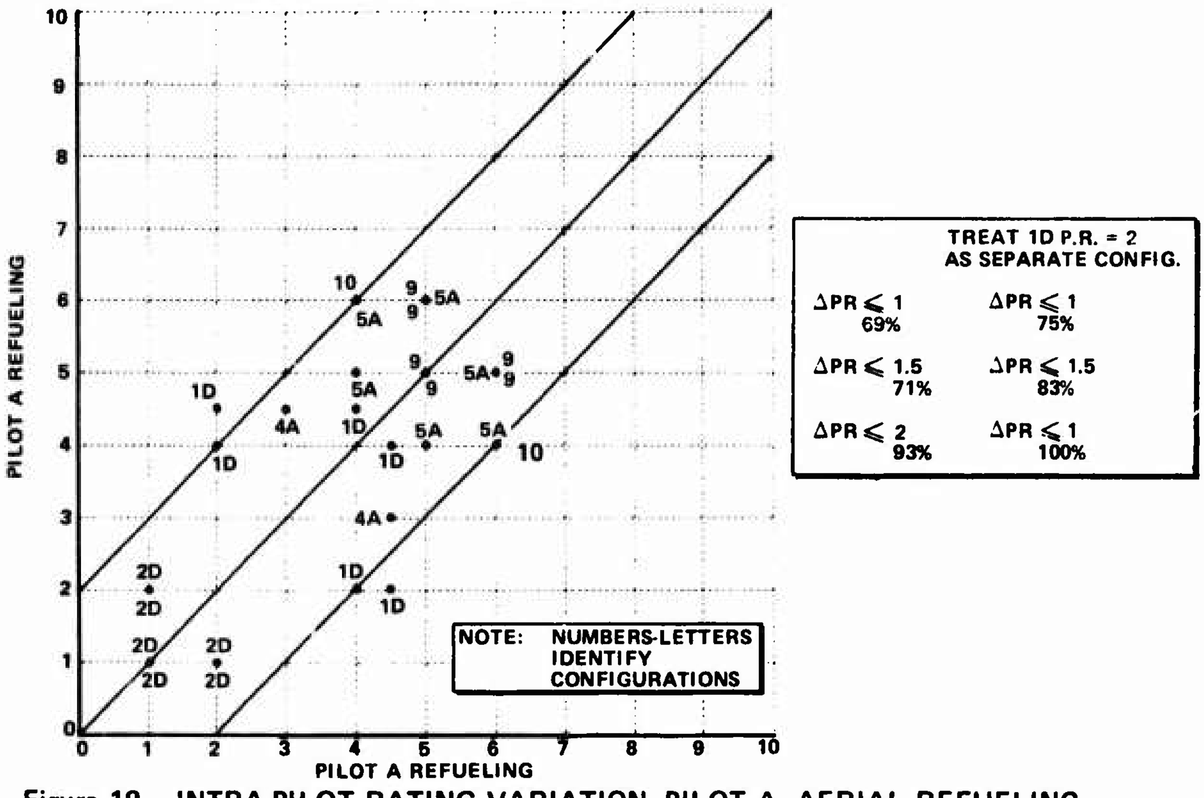


Figure 19 INTRA-PILOT RATING VARIATION, PILOT A, AERIAL REFUELING

variable, points appear at 6, 2 and 6, 4. Likewise, two more points appear at 4, 2 and 4, 6 for a total of six points. Using this procedure, the greatest variation in intra-pilot rating obtained in the experiment for each configuration will appear on the figures as deviation from the line of perfect agreement and no single PR, such as the original one for a given configuration, is weighted more heavily than any other.

Each of the plotted points on the figures is accompanied by a configuration identification. The number of points at any given coordinates can be determined by the number of configuration identification labels accompanying that location. Because of the plotting procedure used, a given configuration identification may be duplicated for a given point.

The percentage of the data points in each figure within the following rating bands about the line of perfect agreement is tabulated on each figure. The rating bands used are $\Delta PR \leqslant 1$, $\Delta PR \leqslant 1.5$ and $\Delta PR \leqslant 2$. Figure 16 shows intra-pilot rating variation for Pilot M of Reference 1. Eighty-one percent of the data lies within a band of ± 2 ratings from the line of perfect agreement. The configurations and the ratings given by Pilot M for cases outside this range are listed below.

Pilot M

Configuration	PR
1A	2*, 6, 4
1C	2*, 5, 3.5
2B	2.5*, 6, 6
6E	5.5*, 8

The asterisk denotes points not included in the analysis of Reference 1. None of the above configurations were evaluated in the current experiment.

Figure 17 shows intra-pilot variation for Pilot W of Reference 1 and for Pilot A (the same pilot) in the current experiment. The data for Pilot A is for repeats with a target. None of the configurations evaluated by Pilot A without a target were repeated without a target. One hundred percent of the data for Pilot A with a target lie within $\Delta PR \leqslant 1$. Eighty percent of the data for Pilot W lie within $\Delta PR \leqslant 2$. The configurations and the ratings given by Pilot W for cases outside this range are listed below.

Pilot W

Configuration	PR
1A	2*, 5
6C	2.5*, 5
7C	4, 1.5

The asterisk denotes points not included in the analysis of Reference 1. Configuration 1A was not evaluated in the present experiment.

Figure 18 compares the ratings of Pilot A without a target with the ratings he gave as Pilot W in Reference 1. Eighty percent of the data in Figure 18 lie within $\Delta PR \leqslant 1$ and also $\Delta PR \leqslant 2$. Two points lie outside the range $\Delta PR \leqslant 2$. These configurations are listed below.

Pilot W and A [No Target]

Configuration	PR, Pilot A	PR, Pilot W
1B	7	3
6C	6	2.5*, 5

Again, one of the ratings by Pilot W for Configuration 6C was considered invalid by the authors of Reference 1 and was not included in their analysis.

The intra-pilot rating variation for Pilot A in the aerial refueling task is shown in Figure 19. Ninety-three percent of the repeat ratings are within $\Delta PR \leqslant 2$. Only for configuration 1D did the repeat ratings differ by more than this range.

Pilot A Refueling

Configuration	PR
1D	4.5, 4, 2

4.3.2 Inter-Pilot Rating Variation

Figures 20 through 23 show the inter-pilot rating variation for the data of Reference 1 and the current experiment. Figure 20 compares pilot ratings for pilots M and W of Reference 1. Seventy-eight percent of the data in Figure 20 are within $\Delta PR \leqslant 2$. The configurations and the pilot ratings for cases outside this range are listed below.

Pilot W Compared with Pilot M

Configuration	PR, Pilot W	PR, Pilot M
1A	2*, 5	2*, 6, 4
7A	2	5, 4
2B	4, 5	2*, 6, 6
6B	4	2.5, 1
6F	8.5, 10	6, 8
7F	7, 7, 7	3, 4, 4
8E	5	2.5, 3

Of this group, only Configurations 6B and 7F were repeated in the current experiment.

Figure 21 compares the data of Pilot A without a target with data for Pilot M of Reference 1. Eighty-three percent of the data in Figure 21 lie within $\Delta PR \leqslant 2$. The configurations and pilot ratings for cases outside this range are listed below.

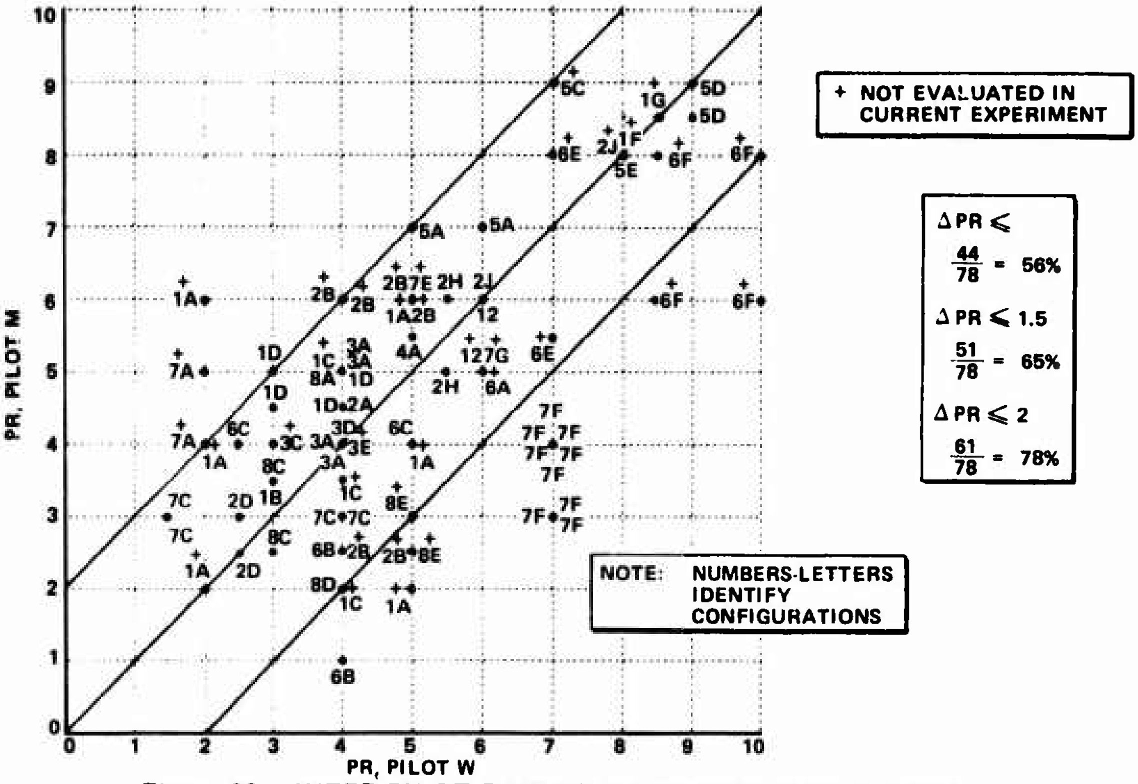


Figure 20 INTER-PILOT RATING VARIATION, REF. 1 DATA

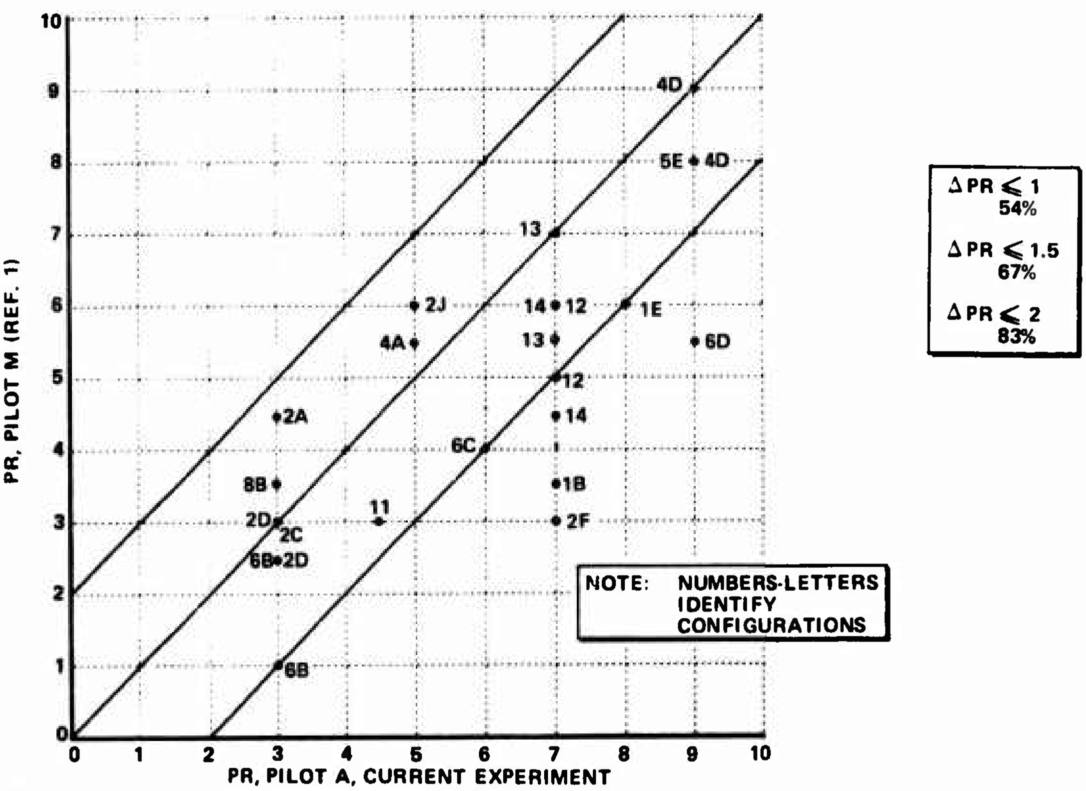


Figure 21 INTER-PILOT RATING VARIATION, PILOT A, NO TARGET (CURRENT EXPERIMENT) VS PILOT M, NO TARGET (REF. 1)

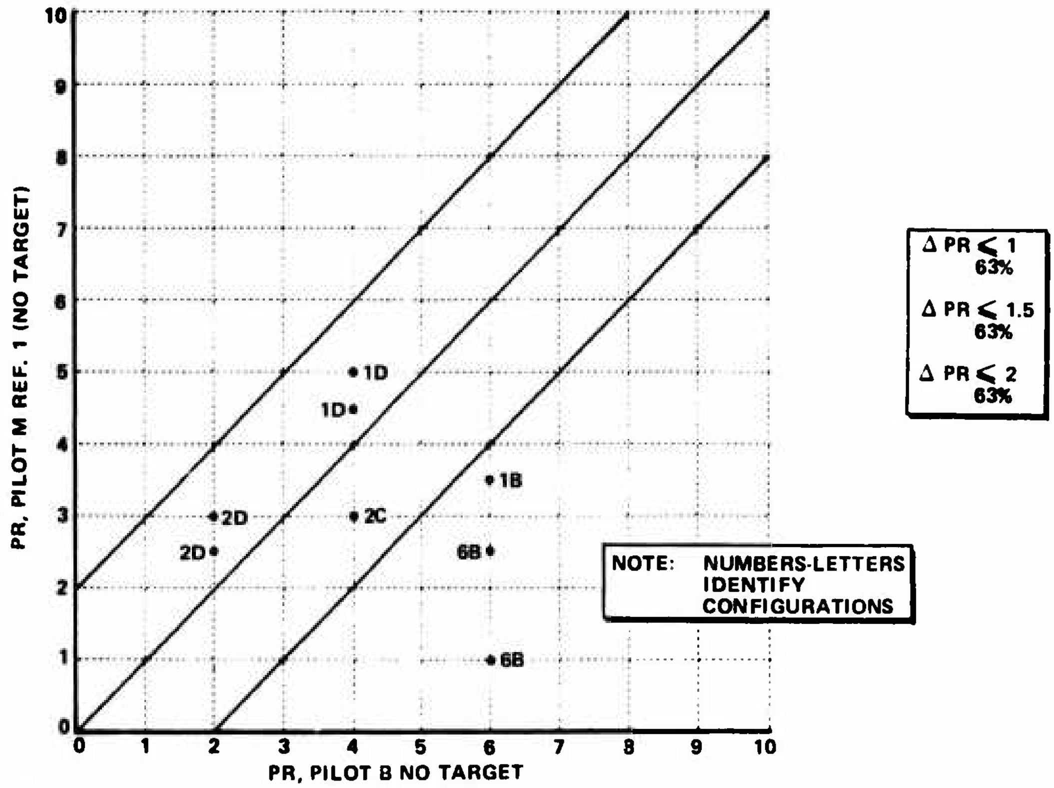
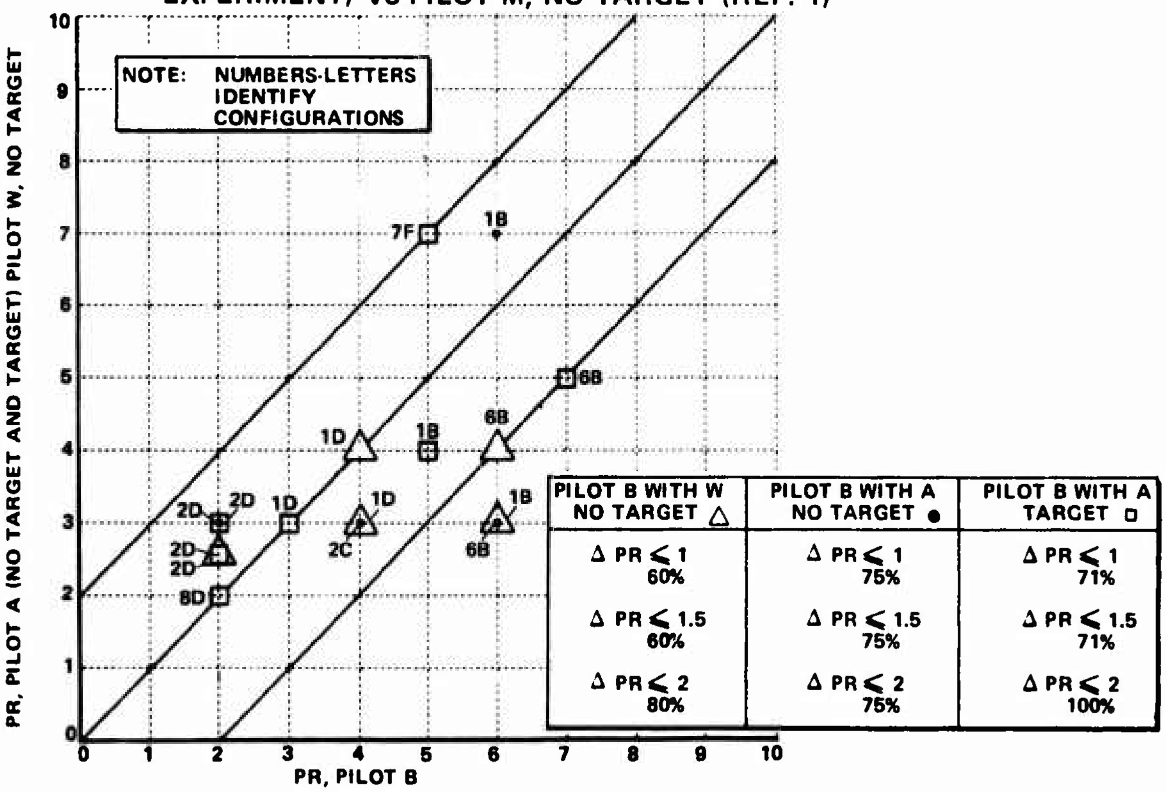


Figure 22 INTER-PILOT RATING VARIATION, PILOT B, NO TARGET (CURRENT EXPERIMENT) VS PILOT M, NO TARGET (REF. 1)



PILOT B WITH W NO TARGET △	PILOT B WITH A NO TARGET ●	PILOT B WITH A TARGET □
Δ PR ≤ 1 60%	Δ PR ≤ 1 75%	Δ PR ≤ 1 71%
Δ PR ≤ 1.5 60%	Δ PR ≤ 1.5 75%	Δ PR ≤ 1.5 71%
Δ PR ≤ 2 80%	Δ PR ≤ 2 75%	Δ PR ≤ 2 100%

Figure 23 INTER-PILOT RATING VARIATION – CURRENT EXPERIMENT

Pilot M Compared with Pilot A [No Target]

Configuration	PR, Pilot A	PR, Pilot M
14	7	4.5, 6
1B	7	3.5
2F	7	3
6D	9	5.5

Figure 22 compares the data of Pilot B, without a target, with the data of Pilot M of Reference 1. Sixty-three percent of the data in Figure 22 lie within $\Delta PR \leqslant 2$. The configurations and pilot ratings for cases outside this range are listed below.

Pilot M Compared with Pilot B [No Target]

Configuration	PR, Pilot B	PR, Pilot M
1B	6	3.5
6B	6	2.5, 1

Figure 23 compares the data of Pilot B, without a target, with the data of Pilot W and Pilot A also without a target. Also compared in Figure 23 are data for Pilots A and B with a target. Eighty percent of the data for Pilot B compared with Pilot W lie within $\Delta PR \leqslant 2$. Seventy-five percent of the data for Pilot B compared with Pilot A, without a target, lie within $\Delta PR \leqslant 2$. One hundred percent of the data for Pilot B compared with Pilot A, with a target, lie within $\Delta PR \leqslant 2$. The configurations and pilot ratings for the cases outside this range are listed below.

Pilot W Compared with Pilot B [No Target]

Configuration	PR, Pilot B	PR, Pilot W
1B	6	3

Pilot A Compared with Pilot B [No Target]

Configuration	PR, Pilot B	PR, Pilot A
6B	6	3

Pilot A compared with Pilot B (Target]

All cases are within $\triangle PR \leqslant 2$ but Configurations 6B and 7F are on the limit; i.e., $\triangle PR = 2$ for these two cases.

The above review of intra- and inter-pilot variability in assigning pilot rating has shown that for eight of the ten comparisons, the portion of data within $\triangle PR \leqslant 2$ was 78 to 100 percent. The other two comparisons had 63% and 75% within the $\triangle PR \leqslant 2$ range. These two groups of data were small, however, so that a single point constituted a large percentage of the group.

This review of the variability in pilot ratings for the data of Reference 1 and the current experiment has identified the configurations for which the pilot rating variation was large. Also, a background has been established judging whether differences in rating between evaluations with and without a target should be considered significant. This background can also be used to determine whether or not differences in rating for ACM with a target and refueling ratings are large enough to be significant. A pilot rating difference of $\triangle PR > 2$ will be used for this purpose.

4.3.3 Comparison of Pilot Ratings for Evaluations With and Without a Target Airplane

Pilot rating data for evaluations with a target are compared with rating data from evaluations without a target in Figures 24, 25 and 26. Figure 24 compares pilot ratings by Pilot A with a target to ratings by Pilot W (the same pilot) in Reference 1 without a target. Seventy-eight percent of the data in Figure 24 lie within $\triangle PR \leqslant 2$. The configurations and the ratings for cases outside this range are listed below.

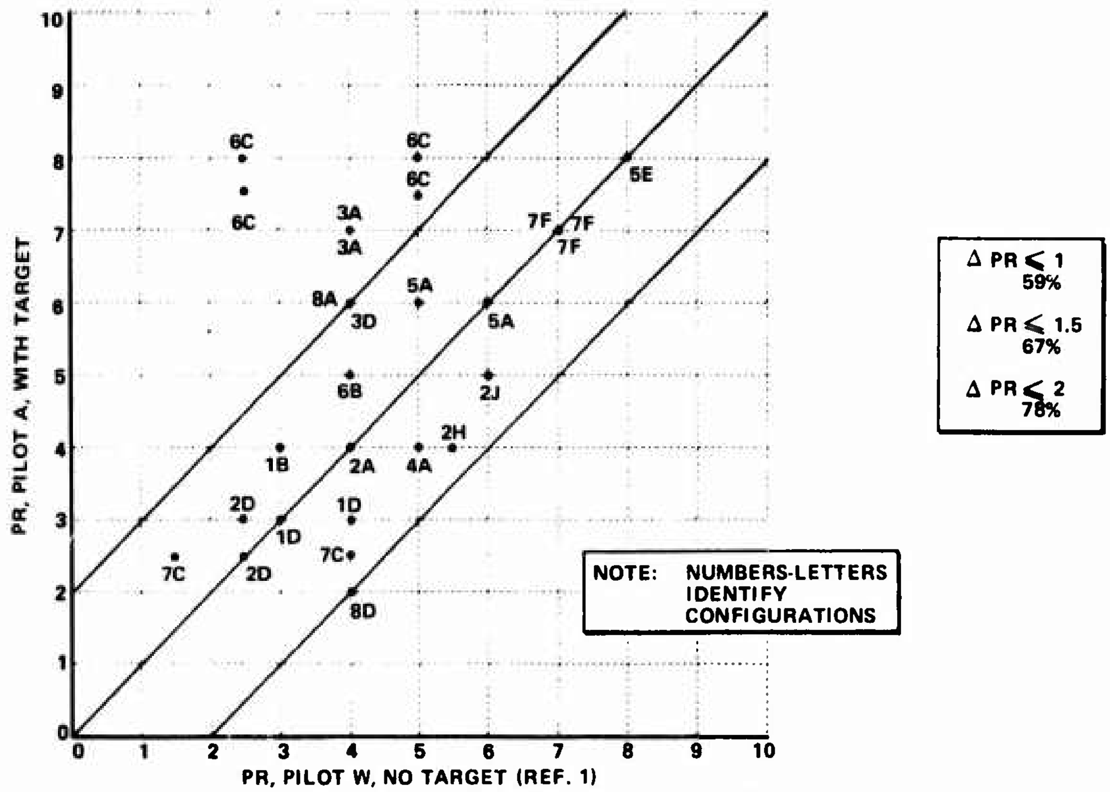


Figure 24 PILOT RATING VARIATION – PILOT A, WITH TARGET VS PILOT W, NO TARGET (REF. 1)

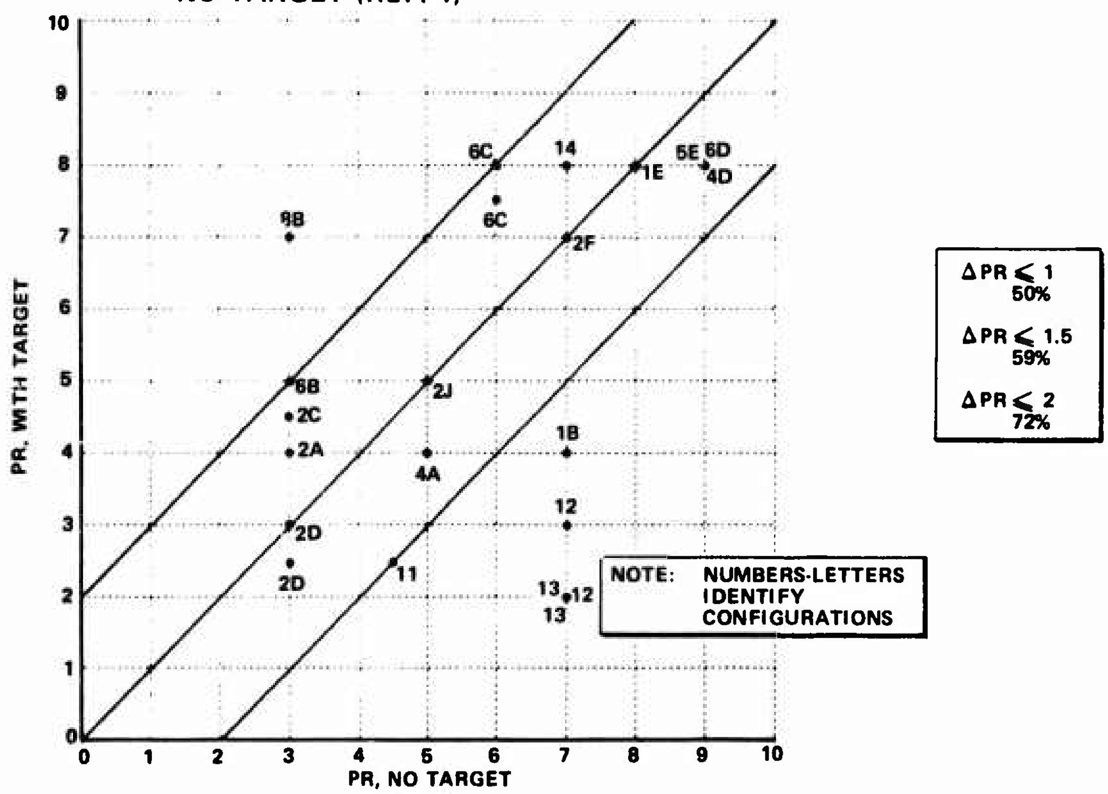


Figure 25 PILOT A RATING VARIATION – WITH TARGET VS NO TARGET

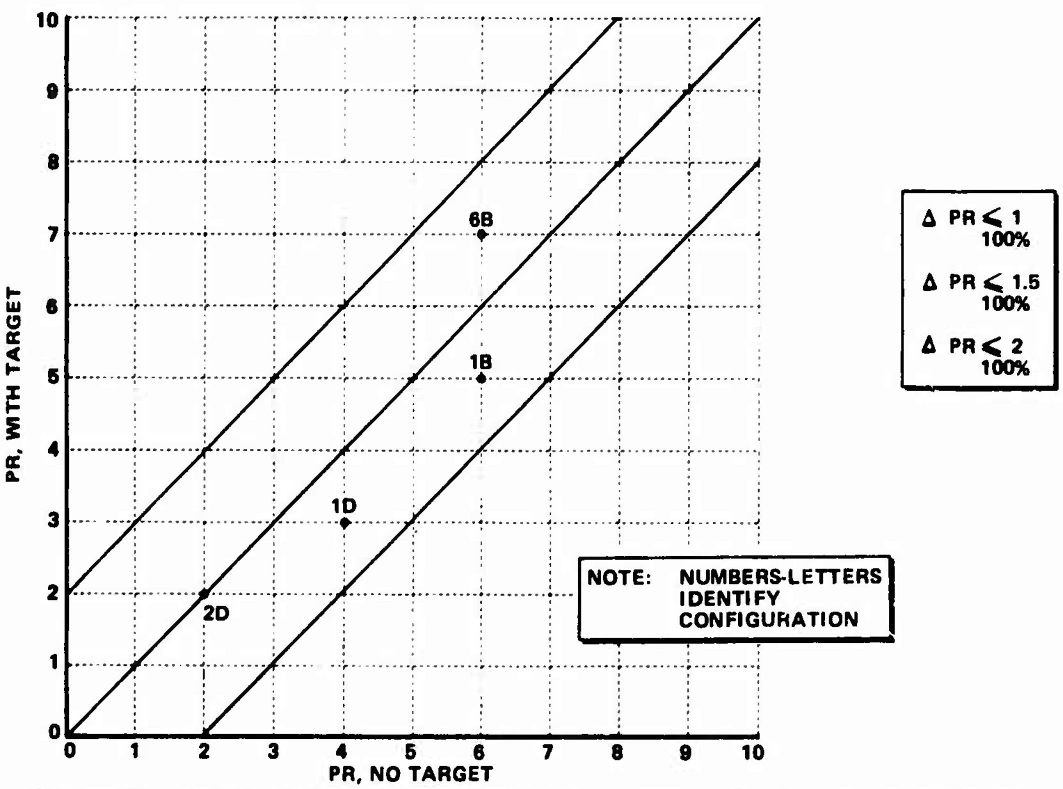


Figure 26 PILOT B RATING VARIATION – WITH TARGET VS NO TARGET

Pilot W [No Target] Compared with Pilot A [With Target]

Configuration	PR, Pilot W	PR, Pilot A, Target
6C	2.5*, 5	8, 7.5
3A	4, 4	7

Figure 25 compares pilot ratings by Pilot A without a target with ratings by Pilot A for evaluations with a target. Seventy-two percent of the data in Figure 25 is within $\Delta PR \leqslant 2$. The configurations and the pilot ratings for cases outside this range are listed below.

Pilot A [No Target] Compared with Pilot A [With Target]

Configuration	PR, No Target	PR, Target
8B	3	7
1B	7	4
12	7	2, 3
13	7	2, 2

Figure 26 compares pilot ratings by Pilot B without a target with ratings by Pilot B for evaluations with a target. One hundred percent of the data in Figure 26 lie within $\Delta PR \leqslant 1$. Thus, for the configurations evaluated by Pilot B, there was no significant difference between target and no target evaluations.

In the following paragraphs, each configuration in the above two listings for Pilot A will be discussed. First, consider Configuration 1B, which appears on the list because Pilot A rated it PR = 7 on his evaluation without a target and PR = 4 on his evaluation with a target. A review of all the evaluations of Configuration 1B shows the following range of ratings:

Pilot, Configuration 1B	No Target PR	Target PR
M	3.5	
W	3	
A	7	4
B	6	5

In all evaluations by all pilots, the comments indicate a potential danger of over stressing the airplane when performing abrupt gross maneuvers such as target acquisition. There was a tendency for the airplane to dig in which required the pilot to slack off and push forward to prevent exceeding the desired pitch rate or load factor. Thus, there was speculation about how severe or potentially dangerous this characteristic might be if aggressive maneuvering were required near the structural limits of the airframe. Pilots A and B made more critical judgments of this danger in their evaluations without a target than they did in their evaluations with a target.

The largest variation in pilot rating was given by Pilot A and W (the same pilot) on two different evaluations without a target. Pilot A commented after his evaluation without a target that the tendency to over g the airplane was a minor objection. As Pilot A, he commented after the evaluation without a target that high g maneuvering must be avoided because of the tendency to over g the airplane. This was the primary reason the airplane was unacceptable.

In this example a large degree of variability resulted for the evaluations without a target. This is in part because the objectional characteristic is critically related to the performance standard the pilot is attempting to achieve, i.e. the more aggressively he attempts to maneuver the more serious the problem. Thus the outcome of the evaluation can be biased by not having the opportunity to do the actual task.

Next consider Configuration 6C. This configuration is in the list because Pilot A rated 6C more severely in his evaluations with a target than Pilot W did without a target. A review of all the rating data for Configuration 6C shows the following ratings:

Configuration 6C

Pilot	No Target PR	Target PR
M	4	
W	2.5*, 5	
A	6	8, 7.5

The PR = 2.5 given by Pilot W was considered to be invalid by the authors of Reference 1. If this rating is disregarded, there is still a large range between evaluations by Pilot W in Reference 1 and evaluations by Pilot A with a target in the current study. Part of this rating degradation is probably a result of the lower short-period frequency in the current program. In the Reference 1 study, Configuration 6C had ω_{SP} = 3.4 rad/sec and in the current study, ω_{SP} = 3.0 rad/sec. This configuration is between the Level 1 and Level 2 lower limits for short-period frequency in MIL-F-8785B (see Figure 2 of this report). The gradient of pilot rating with short-period frequency in this region is known to be quite steep. Thus, part of the rating difference noted between Pilot W in Reference 1 and Pilot A with a target in the current program is attributable to differences in the short-period frequency in the two simulations. The difference in pilot rating for Configuration 6C within the current experiment shows ΔPR = 1.5 and 2 for Pilot A with and without a target. Thus the data indicate a degradation of this configuration when evaluated with a target, but the significance is marginal, i.e., it still could be a result of pilot variability. The pilot comments given by Pilot A in the three evaluations are quite similar. The major objection was the slow initial pitch response requiring the pilot to overdrive the airplane and the resulting unpredictability of the final response. Tracking capability with a target airplane was poor because of the unpredictable response, but normal acceleration control was the primary detrimental feature. The objections to normal acceleration control were voiced somewhat more strongly in evaluations with the target airplane.

Next consider Configuration 3A. This configuration is in the list because Pilot A rated 3A more severely in his evaluation with a target than Pilot W did without a target. A review of all the rating data for Configuration 3A shows the following ratings:

	Configuration 3A	
Pilot	No Target PR	Target PR
M	5, 4	
W	4, 4	
A		7

Configuration 3A was evaluated four times in the study of Reference 1, receiving a PR = 4 three times and a PR = 5. F_s/n was 10.8 lb/g for the PR = 5, and at values of 5.4, 11.5 and 5.7 lb/g for the three PR = 4 cases. This configuration was found to respond quite abruptly initially ($\omega_{SP} \gtrsim 9.5$ rad/sec), and was overly sensitive for small rapid maneuvers. There was a tendency to oscillate when tracking, but this was partially overcome with practice and by flying smoothly. The pilots found they had to hold the stick very lightly, and slow their inputs to reduce the oscillations. Normal acceleration control was considered a good feature of the configuration. As noted in Reference 1, the presence of high-frequency structural oscillations may have influenced how the task was flown and therefore the pilot rating. In the current experiment with a target airplane, this configuration was evaluated with F_s/n = 5.7 lb/g and was assigned a PR = 7. The same problems were noted, including the structural vibration, but instead of just a tendency to oscillate, there was a relatively low-amplitude, high-frequency PIO whenever tracking was attempted. The pilot could stop the oscillation. As he stated, "I really had to back off on my gain to stop the oscillation so that I couldn't really do the job in my estimation." He later said, "I could stop the oscillations by stopping the task." When flying against a target airplane, the pilot could compensate for PIO tendencies only by abandoning the task; but without a target, Reference 1, both pilots said that with practice and smooth flying they could compensate for the oscillatory tendencies. Apparently the target airplane forced the maintenance of performance standards on the part of the evaluation pilot.

Next consider Configuration 8B. This configuration is on the list because Pilot A rated it more severely in his evaluation with a target than he did in his evaluation without a target. A review of all the rating data for Configuration 8B shows the following ratings:

	Configuration 8B	
Pilot	No Target PR	Target PR
M	3.5	
A	3	7

The "no target" evaluation in the current experiment agrees quite well with PR = 3.5 in Reference 1 and PR = 3 in the current study. With a target airplane, the configuration deteriorated to PR = 7. In the study of Reference 1, the configuration was evaluated with $F_s/n = 3.3$ lb/g. The primary objectionable feature of Configuration 8B was a small oscillation about a selected target, and abruptness of response in pitch attitude and normal acceleration. None of the comments showed any very good features. Normal acceleration control was "pretty good" with small oscillations about the desired "g". The response to pilot inputs was "fairly predictable" with stick forces becoming heavier as the response developed. Comments in the present experiment without a target airplane, for which $F_s/n = 4.1$ lb/g, were very similar to those above except that normal acceleration control was considered excellent. The objection was, again, the abrupt initial response and a tendency to overshoot the selected target. The evaluation with a target airplane and $F_s/n = 3.8$ lb/g resulted in a PR = 7. The normal acceleration control was still very good. The airplane was very maneuverable and could be flown aggressively in large-magnitude maneuvering, but attempts at tracking resulted in a nearly continuous PIO. The pilot stated that all he had to do to eliminate the oscillations was "back off on .... gain a little," but anytime a small precise pitch attitude correction was attempted, a PIO would result. For Configuration 8B, the use of a target airplane certainly appears to have affected the results obtained. The oscillation problem was always there, as indicated by the comments on a tendency to overshoot the selected target and the development of a small oscillation in pitch attitude about the selected target. But when the target airplane was tracked, there was little doubt that the oscillatory characteristic was more than just a tendency and resulted in a well-developed PIO.

Consider next Configuration 12. This configuration is on the list because Pilot A rated it more favorably in his evaluations with a target airplane than he did in his evaluation without a target. A review of all the pilot rating data for Configuration 12 shows the following ratings:

	Configuration 12	
Pilot	No Target PR	Target PR
M	5, 6	
W	6	
A	7	2, 3

Configuration 12 showed a quite significant improvement in pilot rating when the evaluation was conducted with a target airplane. With a target airplane, the configuration received PR = 2 and 3. The ratings from Reference 1 were PR = 5, 6 and 6; for the no target evaluation in the current experiment, the pilot rating was PR = 7. In the study of Reference 1, the configuration was evaluated with F_s/n = 4.9, 8.4 and 8.3 lb/g, and the two PR = 6 were for the evaluations with the higher F_s/n values. In all three cases, however, the pilot comments indicate that the stick forces were heavy. Because of the abrupt initial response, the stick forces were initially light, but became heavy as the response developed and remained heavy when maintaining a steady "g" load. The final pitch attitude was difficult to predict and there was an oscillation about the selected target. As a result, tracking capability was poor. Normal acceleration control was good and a desired "g" could be acquired quickly with little overshoot. The main objections were the nose bobbling when trying to stop the nose on a selected target, difficulty in tracking because of nose oscillations, and high steady-state stick forces. In the "no target" evaluation of the current experiment, F_s/n = 5.3 lb/g and PR = 7. The stick forces were light on the initiation of a maneuver, but there were no complaints about heaviness in the steady state. As in the Reference 1 comments, the initial response was too abrupt, the final response unpredictable, and tracking as a result, quite difficult. Normal acceleration control was good and the airplane was easily maneuvered. With a target airplane and with F_s/n = 5.3 lb/g, this configuration was evaluated twice and was assigned PR = 2 and 3. There was no comment about heavy stick forces. The initial response was too abrupt, and there was still the tendency to get a nose oscillation following abrupt inputs during tracking. Tracking capability was good and the pilot stated that he could keep the pipper on the target "with nice smooth corrections." The analysis of Reference 1 predicted a + 4 dB resonance and no requirement for pilot compensation. It was also noted in Reference 1 that the pilot comments were more severe than the predicted resonance would indicate, but the analysis indicated that some difficulty with pitch attitude tracking was likely. The comments from the evaluation with a target airplane imply that some pilot compensation was used since the pilot stated that he could track well using nice smooth corrections. "Smooth corrections" indicates lag compensation or reduced pilot gain. Reduced pilot gain would decrease the resonance. For this configuration, the technique of using a target airplane for evaluations in the ACM mission affected the results and changed a previously unacceptable configuration to a satisfactory airplane. From the pilot comments the configuration exhibited the same characteristics in all evaluations, but with the pipper on a target airplane, the nose oscillations were evidently much less degrading.

Consider next Configuration 13. This configuration is on the list because Pilot A rated it more favorably in his evaluation with a target airplane than he did in his evaluation without a target. A review of all the pilot rating data for Configuration 13 shows the following ratings:

Configuration 13

Pilot	No Target PR	Target PR
M	7, 5.5	
A	7	2, 2

Configuration 13 was rated PR = 5.5 and 7 in Reference 1 by Pilot M with F_s/n = 8.1 and 6.0 lb/g, respectively. In the "no target" evaluation of the current experiment, a PR = 7 was assigned by Pilot A with F_s/n = 5.8 lb/g.

With a target airplane, this configuration was evaluated twice by Pilot A with F_s/n = 5.8 lb/g, receiving a PR = 2 both times. In Reference 1, the pilot comments indicate that it was difficult to select a satisfactory stick force gradient. Somewhat heavy steady forces were selected to improve the abrupt initial attitude response. The response predictability was poor, the nose would overshoot the selected target and then bobble badly on the target; as a result, tracking was difficult.

In the evaluation with no target airplane in the current experiment, the stick forces were "okay". The initial pitch response was abrupt and attempts to stop the nose on a selected point produced a several-cycle oscillation. As before, the tracking was poor because of "high frequency," low-amplitude PIO's. Normal acceleration control was good, but the pilot stated that he had to refrain from "abruptness" and "ease into things." When evaluated with a target airplane, the configuration was satisfactory. Stick forces were good, and the final pitch attitude was predictable. The pilot stated, "There was a tendency to bobble the nose just a little when I really tightened up on the task, but it was still satisfactory." Normal acceleration control was considered excellent. Tracking capability and "g" control were listed as good features, and the only objection, considered minor by the pilot, was a tendency to bobble.

Evidently, the nose bobble or PIO tendency of Configuration 13 was much less degrading when flying against the target airplane than it was judged to be when evaluating without a target airplane. For Configuration 13, as with Configuration 12 above, the technique of using a second airplane for a target in the ACM task affected the experimental results obtained.

Ratings By Pilot A With Target Compared With Pilot M Without Target

Examination of Tables II, III, and IV shows that Pilots A and W did not evaluate Configurations 2E, 9, and 10 without a target. These configurations were, however, evaluated by Pilot M in Reference 1. The pilot ratings of Pilot A with a target are compared with the ratings of Pilot M in Figure 27.

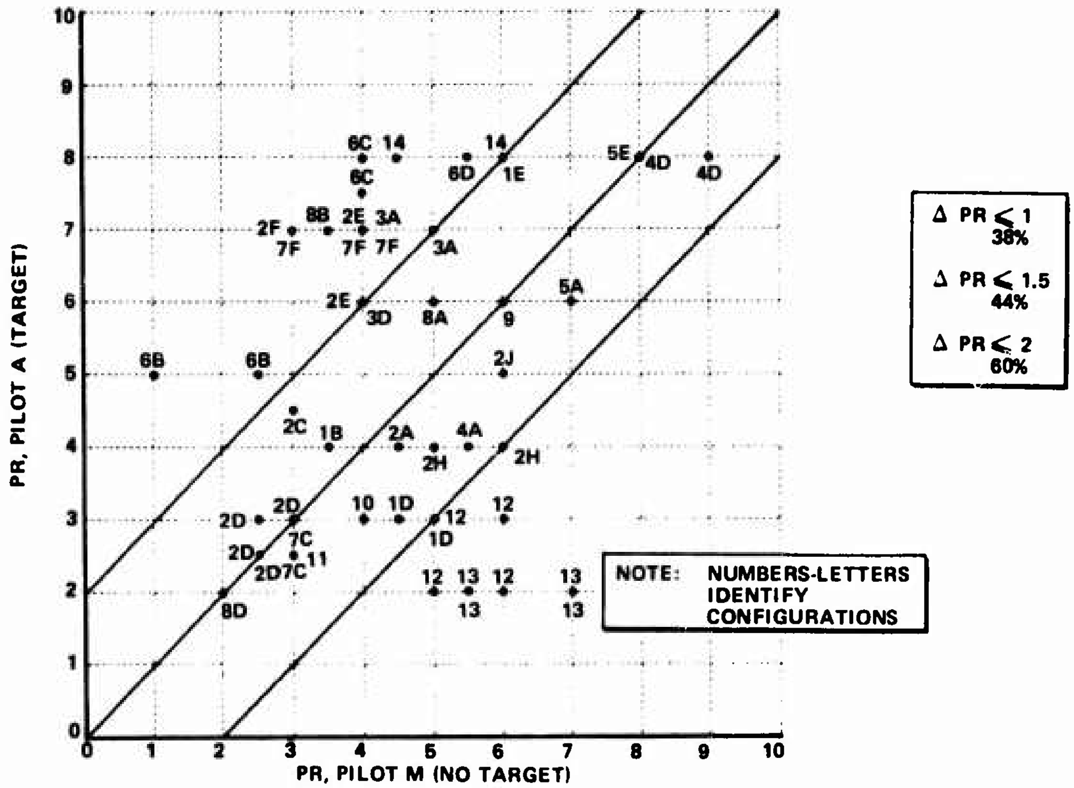


Figure 27 PILOT RATING VARIATION – PILOT A (WITH TARGET) VS PILOT M (NO TARGET)

Sixty percent of the data in Figure 27 lie within $\Delta PR \leqslant 2$. The configurations for which the rating variation exceed $\Delta PR > 2$ are listed below. Pilot ratings for all pilots are listed for these configurations.

	No Target				Target	
Configuration	Pilot M	W	A	B	Pilot A	B
2E	4	-	-	-	7, 6	-
2F	3	-	7	-	7	-
3A	5, 4	4, 4	-	-	7	-
6B	2.5, 1	4	3	6	5	7
6C	4	2.5*, 5	6	-	8, 7	-
6D	5.5	-	9	-	8	-
7F	3, 4, 4	7, 7, 7	-	-	7	5
8B	3.5	-	3	-	7	-
14	4.5, 6	-	7	-	8	-
12	5, 6	6	7	-	2, 3	-
13	7, 5.5	-	7	-	2, 2	-

Many of the configurations in the above list are the same ones in the list that resulted from comparison of "target" ratings from Pilot A with "no target" ratings from Pilots A and W (see Figures 24 and 25). The new configurations are 2E, 2F, 6B, 6D, 7F, and 14. The pilot ratings for the no target evaluations of 6B, 6C, and 6D show considerable variation, with the ratings from the current experiment being generally poorer than the ratings from Reference 1. The short-period frequency for these configurations was lower in the current experiment; therefore, the target ratings should not be directly compared to the no target ratings of Reference 1.

The rating data for Configuration 7F indicate disagreement between Pilots M and W for the no target evaluations that are as large as any of the target - no target variations. Therefore, no conclusion can be drawn about the effect of having a target when evaluating this configuration.

The rating data for Configuration 14 indicate large disagreement between Pilots M and A for the no target evaluations. Because of this disagreement, no significance can be given to the comparison of pilot ratings for Pilot M without a target with ratings from Pilot A with a target.

The ratings for Configuration 2F are similar to those for Configuration 14; again, no significance can be given to the comparison between Pilot M without a target with Pilot A with a target.

Configuration 2E was evaluated once in the study of Reference 1 with $F_s/n = 3.8$ lb/g and was assigned a PR = 4. The objections listed by the evaluation pilot were a tendency to overshoot the target. The pilot stated he had to compensate for this tendency, but that it was not serious. The problem was more pronounced during the IFR tracking tasks. Normal acceleration control was "not too precise." A given g level could be acquired quickly, but there was a tendency to overshoot the desired g. Stick forces were reportedly comfortable, but on the heavy side to reduce the overshoot tendency. Attitude control during tracking was a "not serious" problem with a continual overshoot when tracking. In the present experiment with a target airplane and $F_s/n = 4.2$ lb/g, Configuration 2E received pilot ratings of PR = 6 and 7. The pilot comments for the two evaluations are similar. The major objection was the PIO's induced whenever tracking or when attempting abrupt maneuvers. The pilot stated that he could stop the oscillations by "abandoning the task." Normal acceleration control was one of the better features of the airplane and it could be maneuvered well, but the pilot again stated that any attempt at "tight control" (high gain) would result in a PIO. Stick forces were reported as satisfactory.

In the pilot comment for 2E in Reference 1, the pilot stated that he had to compensate for a "not serious" tendency to overshoot when tracking. In the current experiment, with a target airplane, the pilot experienced PIO problems which could be stopped but he had to abandon the task. When flying ACM against and tracking a maneuvering target airplane, the evaluation pilot cannot both lower his standard of performance and continue to do the job. If he lowers his performance standard, he can no longer keep the target in his gunsight. But, when evaluating without a target airplane, the evaluation pilot may lower his performance standard, continue the evaluation, and measure his required compensation against the decreased performance standard. Since in Reference 1 the pilot said he was able to compensate for the overshoot tendency, he may have decreased his bandwidth or gain which would, according to the Neal-Smith analysis procedure, decrease the closed-loop resonance and result in less tendency to PIO. Hence, in this particular case, the use of a target airplane may have forced the maintenance of performance standards.

Further Discussion of Configurations (2E, 3A, 8B, 12 and 13)

Of the 30 configurations evaluated with a target, the evaluations of 5 configurations (2E, 3A, 8B, 12 and 13) may have been significantly affected by performing the evaluations with a target compared to performing the evaluations without a target. Because Configuration 2E was only evaluated once without a target, and this evaluation was performed by a different pilot, this rating difference will not be further pursued. The other four configurations (3A, 8B, 12 and 13) all had high frequency short period roots and in view of this similarity, all the configurations in Groups 3 and 8 which were evaluated with a target have been listed below, together with Configurations 12, 13 and 14. The pilot ratings by all pilots for evaluations both with and without a target are listed.

	No Target				Target	
Configuration	Pilot M	W	A	B	Pilot A	B
3A	5, 4	4, 4	-	-	7	-
3D	4	4	-	-	6	-
8A	5	4	-	-	6	-
8B	3.5	-	3	-	7	-
14	4.5, 6	-	7	-	8	-
8D	2	4	-	-	2	2
12	5, 6	6	7	-	2, 3	-
13	7, 5.5	-	7	-	2, 2	-

Configurations 3A, 3D, 8A, 8B and 14 were all given poorer ratings for evaluations with a target. Configuration 8D was rated essentially the same for evaluations with and without a target. Configurations 12 and 13 were both rated considerably better in evaluations with a target. Focusing attention on Configurations 12 and 13, it is observed that Configuration 12 is in the Level 1 region of Figure 2 and is also in the Level 1 regions of the parameters A vs $\Delta\measuredangle$ and $\left|\ddot{\theta}/F\right|_{max} \times F_S/n_\gamma$ developed in Reference 4. Thus is terms of correlation with flying qualities parameters, the ratings for Configuration 12 without a target have been anomalous and one would be happy to accept the ratings from the evaluations with a target as the more valid assessment of the flying qualities of this configuration.

Up to this point one could argue that performing evaluations with the target airplane available had revealed a more rapid degradation of flying qualities with increased short period frequency than was found in evaluations without a target and also that an anomaly in evaluating Configuration 12 had been corrected. Unfortunately, the results from evaluations of Configuration 13 are inconsistent with this interpretation which assumes that the more accurate assessments of the flying qualities has in each case, resulted from the evaluations performed with a target available. The ratings for evaluations of Configuration 13 with a target (PR = 2, 2) seem inconsistent with the ratings for Configuration 14 (PR = 8) and Configuration 8A (PR = 6). The short period dynamics, control system and feel system dynamics and command signal used for these three configurations are listed below.

Configuration	PR With Target	η/α	ω_{SP}	ζ_{SP}	ω_3	ζ_3	ω_{FS}	ζ_{FS}	Command Signal
8A	6	50	16.0 rad/sec	.73	75 rad/sec	.67	31 rad/sec	1.0	Stick Force
13	2, 2	50	15.0	.30	75	.67	31	1.0	Stick Position
14	8	50	16.0	.21	75	.67	31	1.0	Stick Position

The most notable differences between these configurations are the different short period damping ratios and the fact that Configuration 8A was done with force commands and Configurations 13 and 14 were done with stick position as the command to the elevator. The short period frequency was slightly lower for Configuration 13. It is difficult to believe that Configuration 13 is really so outstandingly better than Configurations 8A and 14.

Although the evaluation results for Configurations 12 and 13 appear to indicate a very substantial difference between evaluations with and without a target, further comparison with other configurations raises questions as to the validity of this difference in the case of Configuration 13.

4.3.4 Example of Tracking Performance Data

Motion picture records of the pilot's tracking performance were made during the evaluations in which a target airplane was tracked. As an example of the possible correlation of this data with pilot rating some of these records are shown here. Motion picture data was acquired for most of the tracking but reduction of this data for analysis will not be accomplished in this program.

Configuration 2D, $\omega_{sp} \approx 2.5$ rad/sec and $\zeta_{sp} \approx 0.7$, using force commands and negligible control system dynamics, was one of the better configurations in this experiment. Pilot ratings of PR = 3 or better were assigned in all evaluations including those of Reference 1. The only objection the pilots had to this configuration were small oscillations about the selected target when performing evaluations with or without a target airplane.

Figures 28(a) and (b) show the pipper excursions in pitch attitude and laterally during tracking with Configuration 2D. Figure 28(c) is a plot of the range from the target airplane. The bobbles in pitch attitude appear on Figure 28(a), but they are irregular and appear more as pilot corrections rather than any tendency toward a PIO. The pitch excursions in this case are about ±6 mils.

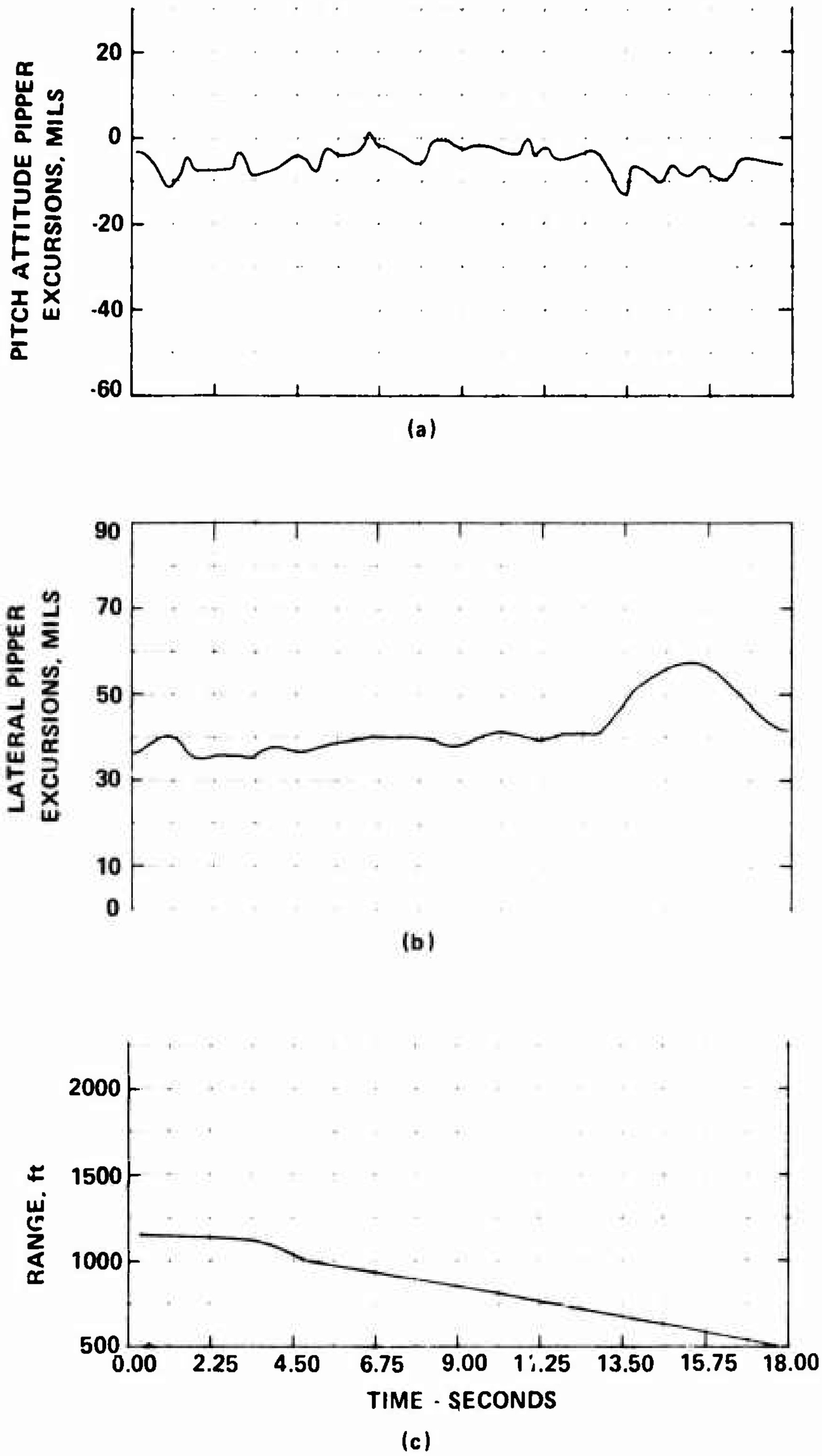


Figure 28 TRACKING PERFORMANCE AND RANGE FROM TARGET AIRPLANE, CONFIGURATION 2D

Figure 29 shows tracking performance for Configuration 4D with $\omega_{sp} \approx 4.5$ rad/sec, $\zeta_{sp} \approx 0.29$. This configuration used force commands and had a first-order control system lag of $T_{z} = 2.0$ seconds or a first order root at $1/T_{z} = 0.5$ 1/sec. The pilots' main complaint for this configuration was the development of a PIO whenever attempting to track or when trying to acquire a predetermined g. In Reference 1, the pilot stated he could greatly improve performance by "backing off in gain." When tracking the target airplane, the pilot found the task "impossible" but said he could eliminate the PIO's by abandoning the task. This configuration received pilot ratings of PR = 8 or 9 in all four ACM evaluations, with or without a target airplane to track. In the current experiment, tracking a target airplane. the frequency of the PIO was approximately 5.5 rad/sec, and from Figure 29, became divergent as the range to the target airplane was decreased. This frequency is near that calculated from the closed loop analysis of Reference 1.

4.3.5 Comparison of Pilot Rating Results in Aerial Refueling Task to Results in the ACM Task

Fourteen configurations were evaluated in the aerial refueling task, all of which were selected from those with $n/\alpha \approx 18.5$ g/rad and were evaluated at an indicated airspeed of 250 knots. The $n/\alpha \approx 50.0$ g/rad cases required an indicated airspeed of 350 knots which exceeded the KA-3 speed limitations for the refueling drogue. The results for the refueling evaluations are shown in Table VII in Section 4.2. The intrapilot rating variation is shown in Figure 30 and was discussed in Section 4.3.1.

Previous sections of this report have compared the target to no target results in the ACM task and the data of the current experiment to that of Reference 1 for the ACM task. Only five configurations showed a significant difference between the target and no target results. All but one of the configurations evaluated in aerial refueling was also evaluated in ACM with a target airplane, the exception being Configuration 5D. Therefore, to determine the influence of the task on handling qualities assessments, the aerial refueling results are compared only to the results of the ACM evaluations

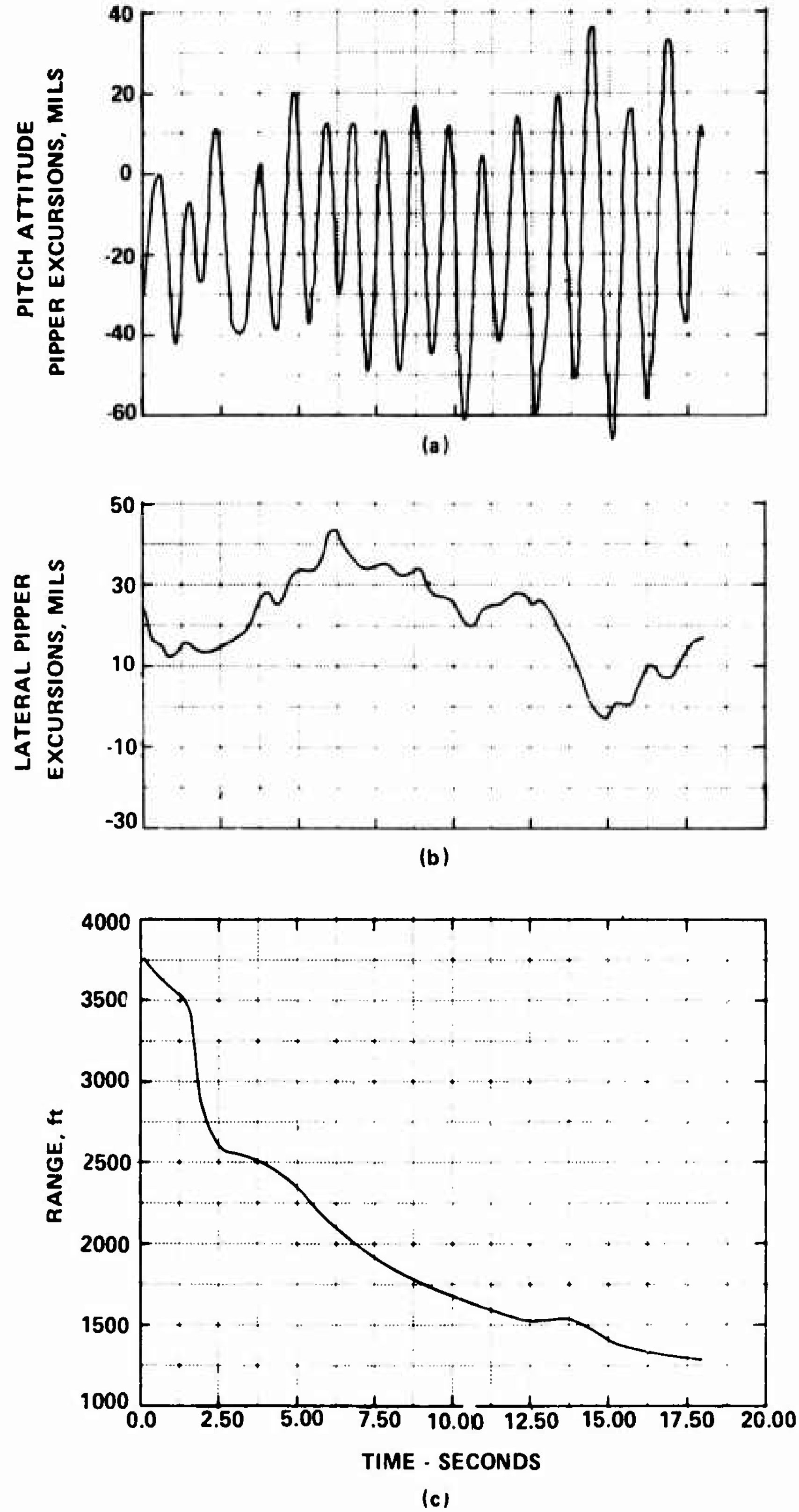


Figure 29 TRACKING PERFORMANCE AND RANGE FROM TARGET AIRPLANE, CONFIGURATION 4D

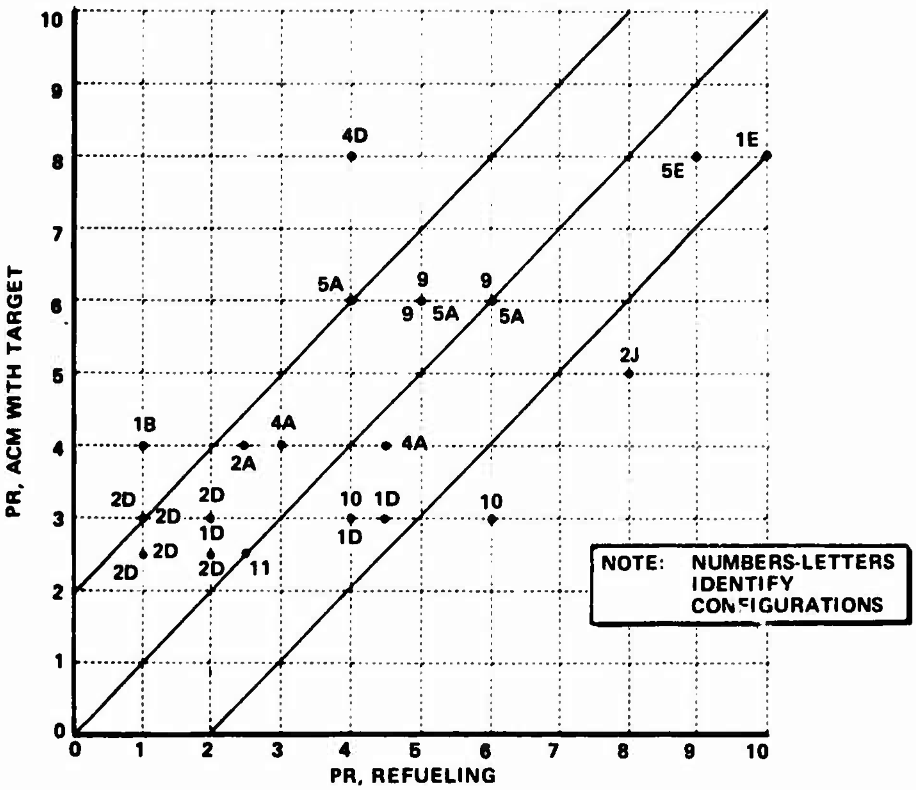


Figure 30 PILOT A RATING VARIATION – ACM WITH TARGET VS AERIAL REFUELING

with a target airplane, as shown in Figure 30. The one exception, as mentioned above, can only be compared to the results of Reference 1, but in this case there was no significant difference in pilot rating.

Of the fourteen configurations evaluated in the aerial refueling task, only four (less than 30%) showed a significant difference in pilot rating between the aerial refueling and the ACM tasks. These were Configurations 1B, 1E, 2J, and 4D. Two other configurations exhibited a marginal difference. Configuration 5A, PR = 6 in the ACM task with a target, was assigned PR = 4,6 and 5 in aerial refueling on successive evaluations. Configuration 10, PR = 3 in ACM received PR = 6 and 4 on successive evaluations of aerial refueling.

Except for Configurations 4D and 5D, all the configurations were evaluated with the same value of F_s/n in the aerial refueling task as was used in the ACM task. The pilot reselected the elevator gearing for Configuration 4D, using 11.1 lb/g instead of the 6.9 lb/g used in the ACM task. Configuration 5D was evaluated with F_s/n = 8.9 lb/g, where values of 11.0, 7.3 and 5.4 lb/g were used in Reference 1. This configuration, however, never was assigned a pilot rating better than PR = 8.

Considering the marginal configurations first, Configuration 5A was evaluated three times and rated PR = 4, 6, and 5 in aerial refueling after receiving a PR = 6 in ACM. In the ACM task the pilot found it difficult to track because of tendencies toward pitch attitude oscillations ($\zeta_{SP} \approx 0.18$) and felt that he had to impart damping with his inputs. He did not feel the oscillations were in the category of a PIO, because his inputs damped the airplane rather than aggravating the oscillations. In the aerial refueling task the same problems were evident. For the evaluation in which the pilot assigned PR = 4, he complained about oscillations when 10 to 15 feet behind the drogue, but stated that when very close in and when accomplishing the hook-up, he had "real fine attitude control." He commented that it was necessary to use very small stick inputs. For the PR = 6 and PR = 5 cases, the pilot still complained about oscillations when approaching the drogue at about 10 to 15 feet and stated that at this distance the oscillations were worse, but smaller oscillations continued as the drogue was approached and during hook-up, causing some hook-ups to be missed. Again, very small inputs were required. From the PIO ratings assigned, PIOR = 3.5 in the ACM and PIOR = 2 in all three refueling evaluations, the oscillations were likely more severe in the ACM, but there is little indication that the task difference had a significant effect on the handling qualities assessment.

Configuration 10, PR = 3 in the ACM task provided good tracking capability and normal acceleration response. The only objection the pilot listed, a minor one, was the slow initial response and a bit of a tendency to overcontrol. For the PR = 6 aerial refueling evaluation, the initial response was reported to be slow and the final pitch attitude response unpredictable. Pitch attitude control and tracking capability were poor. For the PR = 4 evaluation, the pilot still reported the slow initial response, but stated that the pitch attitude control was good and tracking capability was "fair to good." The pilot further reported that at times he "could do a real good job" and at other times he could not. There is little in the pilot comments or on the flight records to indicate why the pilot had more difficulty in one refueling evaluation than in the other. But if the ACM PR = 3 and the aerial refueling PR = 6 are compared, the difference, $\triangle$PR = 3, is certainly significant; or if the average PR during refueling is used (PR = 5) the difference is still significant. Evidently the slow initial response which causes the pilot to overdrive the airplane and leads therefore to an unpredictable final response causes more degradation in the very close and precise task of contacting the refueling drogue than it does in tracking another airplane at a much longer distance.

Configuration 1B was rated PR = 4 and 5 in ACM, and PR = 1 in refueling. In the ACM both pilots objected to the tendency to overcontrol in g for gross maneuvers. The airplane would "dig in." Both pilots listed the tracking capability as a "good feature" although there was a tendency for a slight nose bobble or oscillation. In refueling, the airplane was excellent; the pilot stated he could simply "fly" the probe into the center of the drogue at will. There were no comments about normal acceleration control. Of course, no gross maneuvering is used in the aerial refueling; the task is one of precision formation in level flight and tracking of the drogue. Therefore, the degradation of the airplane in ACM because of poor normal acceleration control had no effect on the aerial refueling performance.

Configuration 4D was also much better for aerial refueling than for ACM. In refueling the configuration was rated PR = 4 with $F_s/n = 11.1$ lb/g as opposed to ACM with PR = 8 and $F_s/n = 6.9$ lb/g. In ACM the pilot found it impossible to track. Any attempts at tracking resulted in large-amplitude PIO's, as shown on Figure 29. Normal acceleration control was poor because of the unpredictable final response and the resulting oscillations about the desired g. In the aerial refueling the pilot reselected the elevator gearing to get heavier stick forces which were acceptable for the aerial refueling task. The $F_s/n = 11.1$ lb/g selected for refueling would probably be too heavy for gross maneuvering in ACM. Even with the heavier stick forces, the pilot still found the final pitch attitude response a little oscillatory. With the heavier stick forces in aerial refueling, the pilot stated that he could impart damping, but with the lighter stick forces in ACM, attempts at pitch attitude corrections resulted in PIO's.

Configuration 1E, PR = 8 in ACM, was "uncontrollable" in the aerial refueling task. In the ACM the normal acceleration control was poor, the airplane was easily overcontrolled, and the pilot usually arrived at a higher g level than he anticipated. There was a fear of overstressing the airplane, tracking capability was poor, and the predictability of the final pitch attitude was poor. The initial response was slow and then the stick forces lightened as the response developed. There were undesirable oscillations, but the pilot described them as not being pilot-induced. In aerial refueling, the pitch attitude response was again described as unpredictable, but the pilot described the oscillations now as being divergent PIO's whenever he tried to track the refueling drogue. He had difficulty with normal acceleration control, and altitude control relative to the tanker was poor with variations described as plus or minus 20 feet. The only way to eliminate the divergent PIO's was to abandon the refueling task and back away from the tanker. The pilot felt that if he continued to attempt refueling he would lose control of the airplane.

Configuration 2J, in ACM, was slow to respond in pitch attitude to pilot inputs, and the final pitch attitude response was unpredictable. Because of a one- or two-cycle oscillation about the desired final pitch attitude, tracking the target airplane was difficult. Assigning a PR = 5 in ACM, the pilot stated that the airplane was maneuverable, he had good g capability, but tracking capability was "only fair." Attempts at refueling with Configuration 2J resulted in a "somewhat divergent" PIO. The closer the airplane approached the refueling drogue, the worse the PIO would become. To stop the PIO, the task had to be abandoned. The pilot said he had to just "freeze the stick" and back away from the tanker to stop the PIO. For aerial refueling, the airplane was assigned a PR = 8.

From the above discussion, it appears that precise pitch attitude control is essential for the aerial refueling task. In three cases above (Configurations 1E, 2J and 1O), the ACM tracking capability was acceptable or satisfactory. But when refueling was attempted, the pilot found he could not precisely control pitch attitude and often developed large or even divergent PIO's. Because aerial refueling is accomplished in nearly straight and level flight, the pilot need not be concerned about load factor limits and normal acceleration control during maneuvers. If the airplane was poor in ACM because of poor normal acceleration control, but was satisfactory for tracking in ACM, then it was satisfactory for refueling. Configuration 4D was PIO-prone in ACM but in aerial refueling, using higher stick forces, there was less tendency toward oscillations. In this case, the improvement in the PR for the aerial refueling task was due to the pilot's being able to select the control gain to optimize pitch attitude control for small inputs without regard to the need to maneuver at high load factor.

Section V

CONCLUSIONS FROM THE PHASE I EXPERIMENT

Selected configurations from AFFDL-TR-70-74, Reference 1, were re-evaluated in the air-to-air combat Flight Phase using a maneuvering airplane for a target instead of having the evaluation pilot perform maneuvers which are considered to be typical of air-to-air combat. A portion of these configurations were also evaluated in the aerial refueling Flight Phase (using probe and drogue equipment) to determine the effect of task on the flying qualities assessment. Conclusions derived from the experiment are as follows.

1. The evaluations performed without a target airplane were adequate to reveal potential flying qualities problems in the detailed pilot comments in all cases.

2. The intra and inter-pilot rating variability was smaller for evaluations with a target airplane and for the refueling evaluations than it was for the evaluations performed without a target.

3. There was some indication that the flying qualities of configurations with high frequency short period roots (3A, 8B and 14) were rated worse when evaluated with the target airplane available than without it. These configurations were rated worse because the tendency for high-frequency low-amplitude pitch oscillations was more severe in evaluations with the target airplane available. This trend can not be stated as a firm conclusion however, because the ratings for Configurations 12 and 13 exhibited the opposite trend. The ratings for Configuration 13 with a target seem inconsistent with the ratings for Configuration 8A, 8B and 14 which are in the same "neighborhood". Thus although evaluation of Configuration 13 with a

maneuvering target resulted in grossly different pilot ratings than were obtained from evaluations without a target, the actual acceptability of Configuration 13 is still unresolved.

4. The complaint of abruptness in the initial response and the occurrence of a small-amplitude high-frequency pitch oscillation is typical of the high frequency short period configurations. The severity of the complaint is dependent on how aggressively the pilot maneuvers the airplane and how precisely he attempts to track the target or display task. Variability in the way the pilot attempts to execute the task is thought to be reflected in the pilot ratings.

5. Evaluations of flying qualities configurations for the Air Combat Flight Phase should be performed with a target airplane performing evasive maneuvers. The use of a target airplane in the evaluation process will not guarantee that rating anomalies will not occur, and therefore, there is still a need for evaluations by more than one pilot and repeat evaluations by each pilot.

6. Care must be taken in defining the evaluation task involving the target airplane so as not to compromise the total ACM task by undue emphasis on one part such as tracking at the expense of target acquisition and gross maneuvering.

7. It was the experience in this research program that a target airplane and a refueling tanker were not always available. Because of this, there were delays in the evaluation program and a tendency to perform shorter evaluations so that more configurations could be examined per flight when the other airplanes were available. This may have caused greater variability in the pilot ratings than would have occurred if more time could have been spent on each evaluation and if the evaluation phase could have been executed with less delay.

8. The T-33 airplanes were operated under a 3 g structural limit during this program because of indications in the T-33 fleet of wing structural weakness. This limitation on maneuver magnitude may have had an unknown effect on the evaluation results.

9. Because of the difficulty of getting a refueling tanker for the experiment, only a few configurations could be evaluated for this task, and these evaluations were all performed during five flights. The limited data indicates the following results.

   a. Configuration 1B, which was given poor pilot ratings because of unsatisfactory normal acceleration control in the air-to-air combat maneuvering, was satisfactory for aerial refueling. For this configuration, control of pitch attitude during stabilized tracking was good.

   b. Configuration 4D was evaluated as unacceptable for air-to-air combat, PR=8, because of severe pilot-induced oscillations. This configuration was evaluated as acceptable, PR=4, for refueling after the pilot reduced the control gain; i.e., increased the stick force per g. This example suggests that configurations that are downgraded for air-to-air combat because of control sensitivity and PIO problems may be acceptable for refueling if the control gain is optimized for that task.

   c. Configuration 2J was rated unsatisfactory (PR=5) for air-to-air combat because of control problems resulting from excessive lag in the control system. This configuration was rated unacceptable (PR=8) for refueling because the control system lag caused a PIO during attempts to engage the refueling drogue with the receiving probe.

10. The data from this experiment should be analyzed in terms of the closed loop parameters developed in Reference 1 and in terms of the open loop parameters developed in Reference 4 to determine the effect of the new data on the validity of the criteria proposed in these references.

Section VI
DESCRIPTION OF PHASE II EXPERIMENT

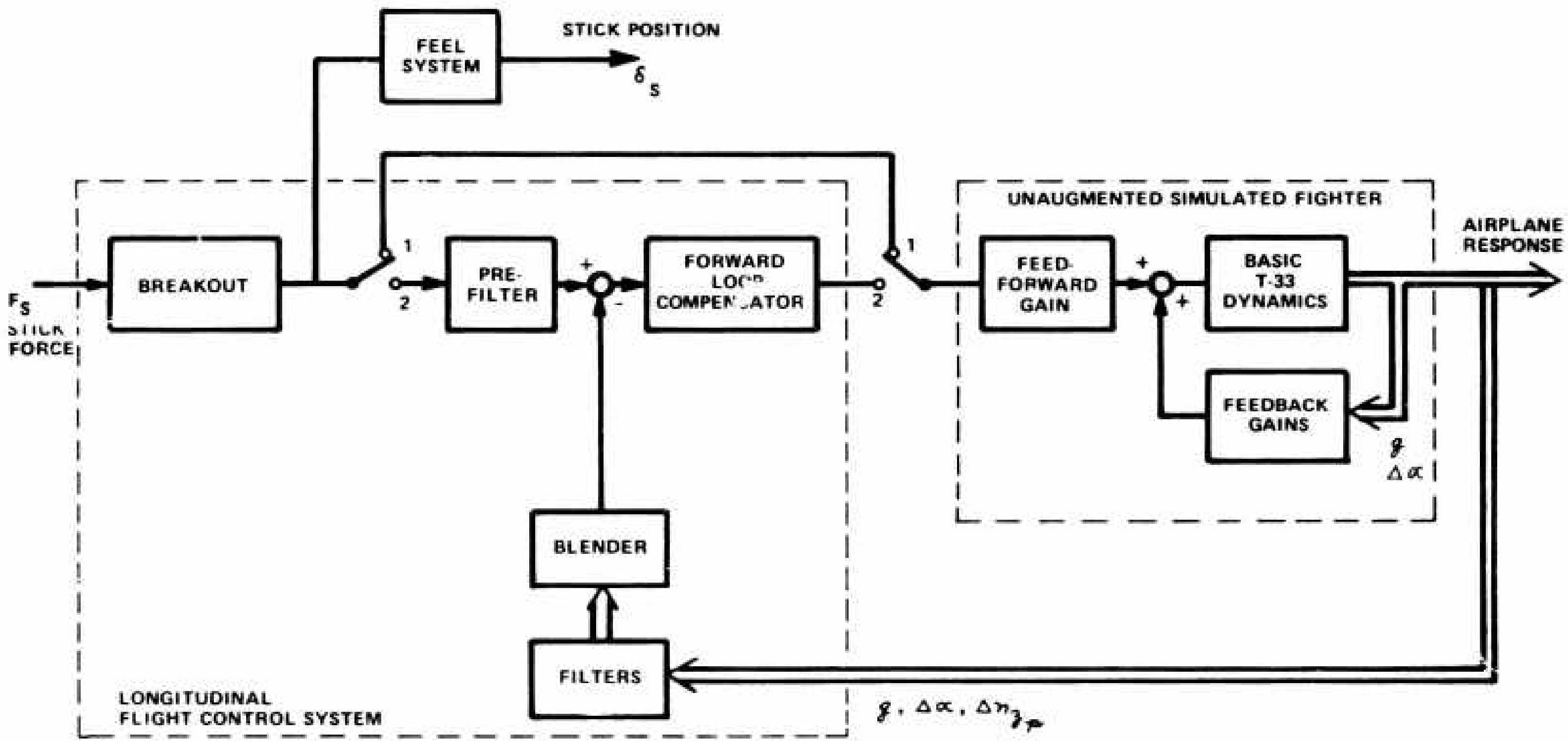
6.1 TEST PROGRAM

As previously mentioned, the purpose of Phase II of this experiment was to investigate the overall systems criteria for the flying qualities of highly augmented aircraft. A portion of the work was the development of design criteria for the overall flight control-augmentation system that would be applicable over a fighter mission profile which included several typical fighter tasks. For this phase of the experiment, the NT-33A was augmented by the variable stability system (VSS) to produce flight characteristics similar to those of a representative unaugmented high-performance fighter airplane. Four flight control systems were designed and tested to demonstrate that Level 1 flying qualities could be obtained for several Flight Phases typical of the fighter mission.

6.1.1 Configurations Evaluated

The four flight control systems were designed and mechanized around the simulated airplane represented by the NT-33A and its variable stability system, Figure 31. The evaluation configurations were the unuagmented simulated airplane and the simulated airplane as augmented by each of the four flight control systems. A tabular summary of the resulting five evaluation configurations is listed below:

Configuration	Feedback Signals	Integration in Forward Loop	Prefilter Frequency
II-1	None	No	None
II-2	α, q	No	None
II-3	α, n_z, q	No	None
II-4	n_z, q	No	None
II-5	n_z, q	Yes	4 rad/sec



POSITION 1: CONTROL SYSTEM DISENGAGED
POSITION 2: CONTROL SYSTEM ENGAGED

Figure 31 SYSTEM CONFIGURATION SCHEMATICS

Configuration II-1 was the unaugmented simulated airplane, and each of the remaining four configurations represented the application of four different flight control and augmentation systems.

6.1.2 Mission Profile and Design Flight Conditions

Before a flight control augmentation system design could commence, it was necessary to define both the mission profile over which the simulated aircraft was to operate and some specific design flight conditions. This procedure began with the selection of a flight envelope, h-M diagram of a representative modern, high-performance fighter aircraft, Figure 32. A condition placed on the flight control system design was that each system provide longitudinal handling qualities that would meet the Level 1 requirements of MIL-F-8785B over an extended portion of the flight envelope and in the tasks that a fighter aircraft is expected to perform. To meet such a condition the design flight conditions had to be selected to cover a range from landing approach to high-altitude supersonic flight. The flight conditions selected are shown as sequence 1 through 6 in Figure 32. These flight conditions include high- and low-altitude supersonic flight and high- and low-altitude low-speed flight.

As mentioned above, the flight control systems designed also had to meet the Level 1 longitudinal handling requirements of MIL-F-8785B in the tasks that a fighter aircraft is expected to perform, including:

(1) Ground Attack

(2) High Altitude Air-to-Air Intercept Tracking

(3) Air Combat Maneuvering

(4) Power Approach

The test program, then, essentially consisted of an in-flight evaluation of the five evaluation configurations. The evaluations were conducted over the

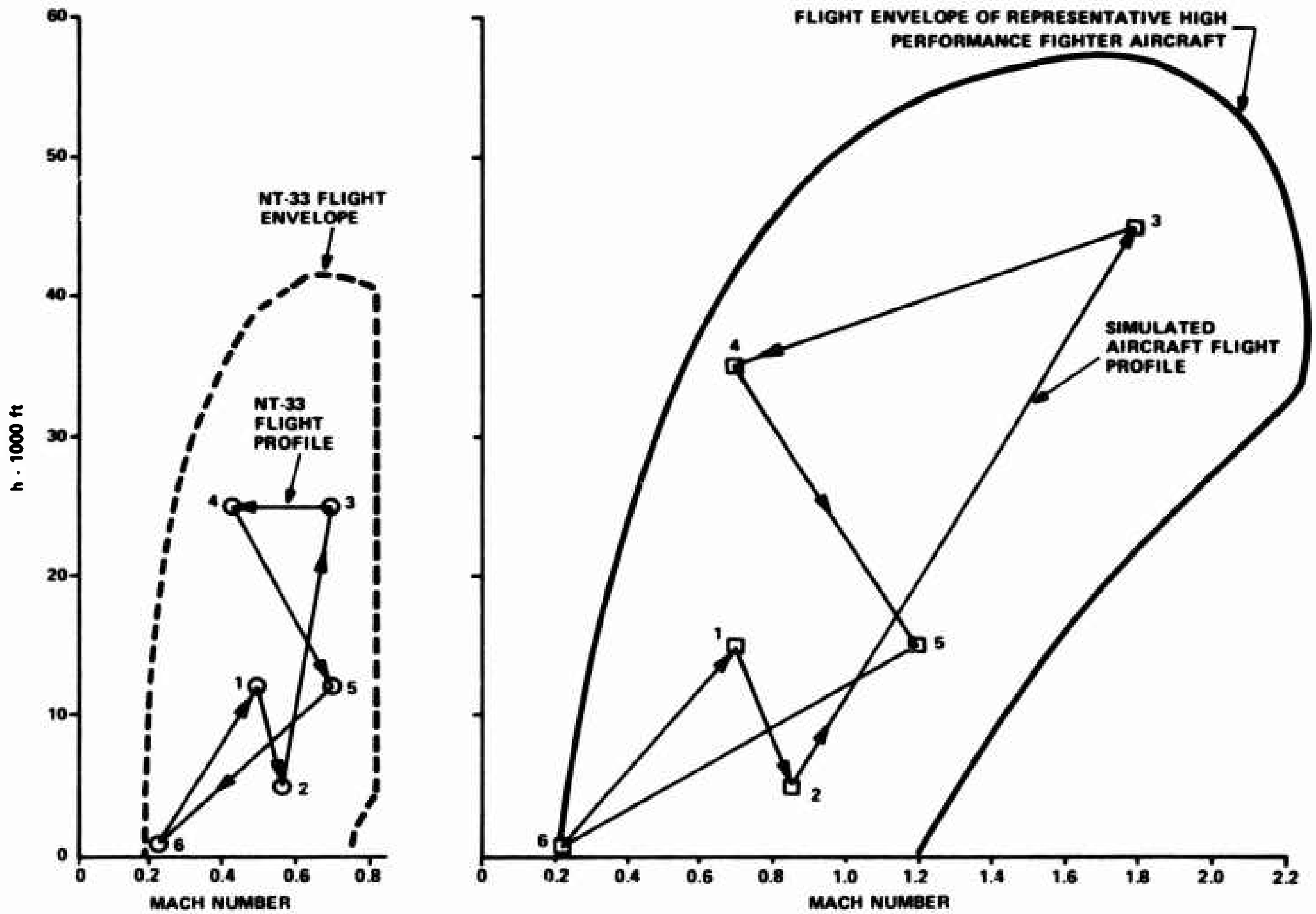


Figure 32 NT-33A AND SIMULATED AIRPLANE MISSION PROFILES

simulated mission profile shown in Figure 32, with the evaluation pilot performing the above four tasks at appropriate points in the mission profile. Before proceeding further into the details of the flight tests, it is necessary to describe the flight control system criteria, the modification of the NT-33A VSS to simulate the unaugmented airplane, and the design philosophy and procedure for development of the flight control augmentation systems evaluated.

6.2 IN-FLIGHT SIMULATION OF THE UNAUGMENTED AIRCRAFT

The purpose of this section is to describe the longitudinal characteristics of the unaugmented simulated aircraft and the modification of the existing NT-33A VSS to achieve the desired in-flight simulation of this aircraft. A point to be stressed here is that the essential characteristics of the unaugmented simulated aircraft are those typical of modern high performance fighter aircraft; it was not an intent to simulate a specific aircraft. The NT-33A VSS was modified and used to simulate the varying characteristics of the unaugmented aircraft over the flight envelope as indicated in Figure 32.

6.2.1 Longitudinal Characteristics of the Unaugmented Simulated Aircraft

The many flight parameters that influence the longitudinal dynamic characteristics of the modern high-performance fighter aircraft include, for example, dynamic pressure, angle of attack, c.g. location, Mach number, and altitude. However, since the major interest of this research program was to focus on and accentuate the essential features with which the designers must cope in synthesizing the flight control systems for this type of aircraft, the following relationships were used for the three major stability and control derivatives of the longitudinal short period dynamics.

$$M_{\delta_e} = \frac{\bar{q} S \bar{c}}{I_y} C_{m_{\delta_e}} = f_1 (\bar{q}) \tag{6.1}$$

$$M_\alpha = \frac{\bar{q} S \bar{c}}{I_y} C_{m_\alpha} (\alpha, \text{c.g. location}) = f_2 (\bar{q}, \alpha, \text{c.g. location})$$

$$M_q = \frac{\bar{q} S \bar{c}}{I_y} \frac{\bar{c}}{2V} C_{m_q} = f_3 (\bar{q}, V)$$

The use of these functional relationships also substantially simplified the in-flight simulation, as discussed later in this section. In equations (6.1) the values of $C_{m_{\delta_e}}$ and C_{m_q} were assumed to be constants and were chosen to be

$$C_{m_{\delta_e}} = -0.53 \quad \text{1/rad}$$

$$C_{m_q} = \frac{\partial C_m}{\partial\left(\frac{q\bar{c}}{2V}\right)} = -3.35^{*} \qquad (6.1a)$$

respectively. As indicated in (6.1), C_{m_α} is a function of α and c.g. location. This functional relationship is shown in Figure 33. The effect of Mach number was also included in C_{m_α} as an effective c.g. shift; when passing through the transonic speed range, the effective shift in the aerodynamic center was mechanized as a function of time through use of a first-order filter with a two-second time constant to simulate a smooth transition. The safety pilot

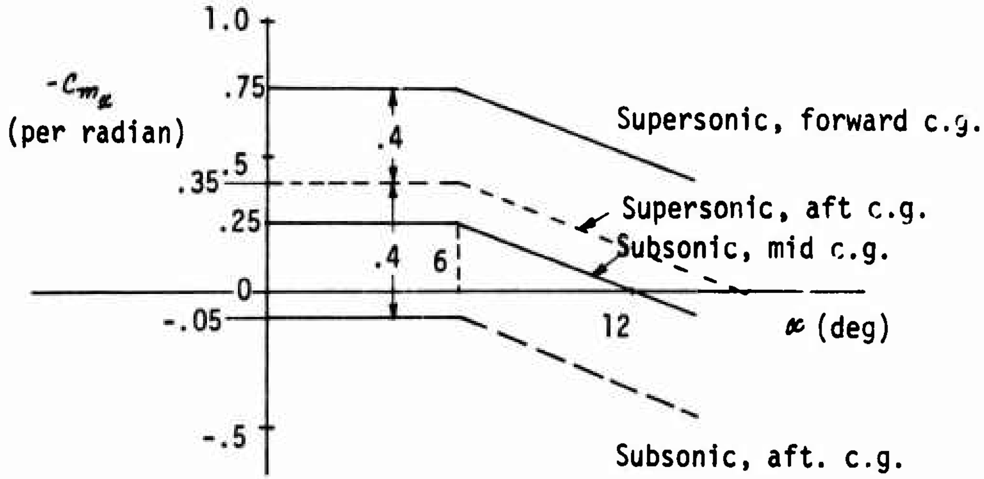


Figure 33 C_{m_α} FOR THE UNAUGMENTED SIMULATED AIRCRAFT

operated a switch ON and OFF at an appropriate flight condition to realistically simulate the Mach effect on C_{m_α} of the simulated aircraft. The total C_{m_α} was mechanized as shown in Figure 34.

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*This value was used in calculating M'_q, thus including the effect of $C_{m_{\dot{\alpha}}}$

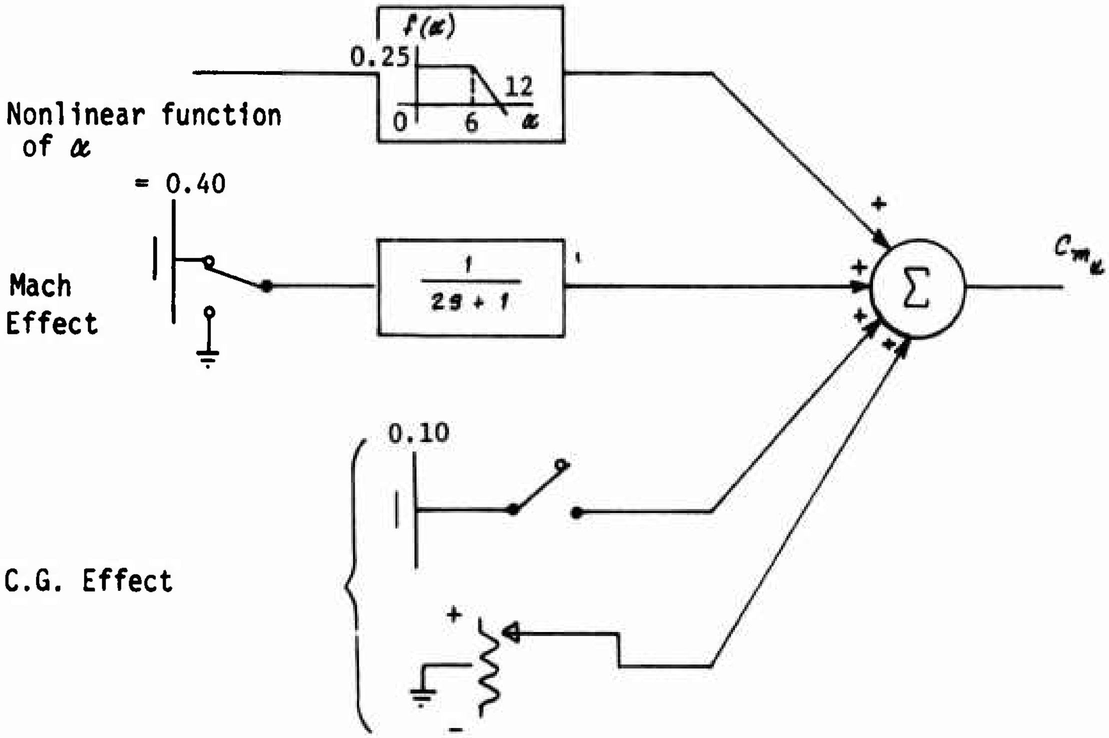

Figure 34 MECHANIZATION OF C_{m_α}

Table VIII compares the M_α, $M_{\dot{\alpha}}$, and M_{δ_e} of the unaugmented simulated aircraft with those of the F-4E at gross weight = 38,735 lb, c.g. = 0.306 $\bar{c}$, in a clean configuration (Ref. 10). Recall once again that the purpose of this in-flight investigation was not to simulate a specific aircraft such as the F-4E. Table VIII instead, compares the possible range of parameter values that can be simulated, and shows that these values are representative of a high-performance fighter aircraft.

Note also that the derivatives Z_α and Z_{δ_e}, which also influence the short-period dynamics, are characteristics of the NT-33A airframe, and they will not be affected by the VSS. The lateral-directional characteristics of the simulated aircraft are discussed in paragraph 6.5.2.

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10. R.L. Kisslinger and G.J. Vetsch, "Survivable Flight Control System Interim Report No. 1 Studies, Analyses, and Approach," AFFDL-TR-71-20, Supplement 2, May 1971.

Table VIII
COMPARISON OF UNAUGMENTED F-4E AND SIMULATED UNAUGMENTED AIRCRAFT

M_α, M_q, M_{δ_e}

Flight Condition	Mach No.	Height (ft)	M_α (1/sec^2)			$\hat{M}_q = M_q + M_{\dot{\alpha}}$ (1/sec)		$\hat{M}_{\delta_{ec}}$ (1/sec^2)	
			GW 38,732 lb F-4E (.31 $\bar{c}$)	Simulated Aircraft		F-4E	Simulated Aircraft	F-4E	Simulated Aircraft
				Most Fwd. c.g.	Most Aft c.g.				
1	0.7	15,000	-5.2	-7.8	1.1	-0.86	-0.80	-12.4	-11.8
2	0.85	5,000	-14.5	-23.7	3.7	-1.41	-2.00	-25.4	-36.3
3	1.80	45,000	-25.0	-21.7	-9.9	-0.38	-0.50	-13.9	-15.7
4	0.7	35,000	-2.0	-2.3	0.70	-0.41	-0.30	-5.4	-4.0
5	1.2	15,000	-39.1	-61.3	-27.8	-1.70	-1.80	-39.9	-44.4
6	0.206	0	-0.04	-1.6	0.17	-0.42	-0.50	-2.1	-2.4

6.2.2 Method of Simulation

To realistically simulate the short-period dynamic characteristics of the unaugmented airplane that continuously vary in the desired manner with flight conditions along the flight profile described above, the existing NT-33A VSS was modified. The modification involved mechanizing the feedforward gain $K_f = \delta_e/\delta_{e_c}$ and the feedback gains $K_\alpha = \delta_e/\Delta\alpha$ and $K_q = \delta_e/q$ as functions of flight conditions.

Figure 35 is a block diagram of the modified mechanization of the VSS.

(SHOWN WITH CONTROL SYSTEM DISENGAGED)

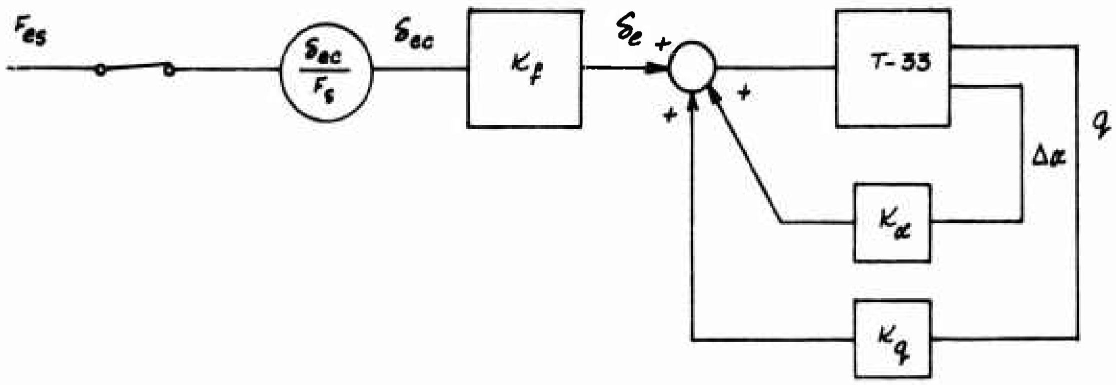

Figure 35 MODIFIED VSS MECHANIZATION

To achieve desired values of M_{δ_e}, M_q, and M_α in (6.1), the required feedforward and feedback gains are given by:

$$K_f \triangleq \frac{\delta_e}{\delta_{ec}} = \left(\frac{K_c}{K_{c_T}}\right)\left(\frac{\bar{q}}{\bar{q}_T}\right)\frac{C_{m_{\delta_e}}}{C_{m_{\delta_{eT}}}}$$

$$K_q \triangleq \frac{\delta_e}{q} = \frac{1}{C_{m_{\delta_T}}}\left[\left(\frac{K_c}{K_{c_T}}\right)\left(\frac{\bar{q}}{\bar{q}_T}\right)\frac{\bar{c}}{2V}C_{m_q} - \frac{\bar{c}_T}{2V_T}C_{m_{q_T}}\right] \quad (6.2)$$

$$K_\alpha \triangleq \frac{\delta_e}{\Delta\alpha} = \frac{1}{C_{m_{\delta_T}}}\left[\left(\frac{K_c}{K_{c_T}}\right)\left(\frac{\bar{q}}{\bar{q}_T}\right)C_{m_\alpha} - C_{m_{\alpha_T}}\right]$$

where $K_c = S\bar{c}/I_y$ and the subscript T denotes the NT-33A basic aircraft. For specific simulation in this program, constant values of $C_{m_{\bar{q}_T}}$, $C_{m_{\delta_T}}$, and $C_{m_{\alpha_T}}$ were used, although these coefficients are, in general, functions of Mach number (and c.g. location for $C_{m_{\alpha_T}}$), as shown in Reference 6. The values used in this simulation were

$$\left.\begin{aligned} C_{m_{\delta_T}} &= -0.92 \quad \text{(1/rad)} \\ C_{m_{\bar{q}_T}} &= -10.50 \text{ (including } C_{m_{\dot{\alpha}_T}} \text{ 1/rad)} \\ C_{m_{\alpha_T}} &= -0.56 \quad \text{(1/rad)} \end{aligned}\right\} \tag{6.2a}$$

The term $\left(\frac{K_c}{K_{c_T}}\right)(\bar{q}/\bar{q}_T)$ in equations (6.2) was calculated using the following geometrical values:

	Simulated Aircraft		NT-33A
S	530 ft^2		235 ft^2
$\bar{c}$	16.05 ft		6.72 ft
I_y	180,000 slug-ft^2	(@ takeoff)	20,000 slug-ft^2
	120,000	(@ landing)	

and the flight conditions shown in Figure 32. However, to simplify the in-flight simulation, the following linear approximation was employed in this program:

$$\left(\frac{K_c}{K_{c_T}}\right)\left(\frac{\bar{q}}{\bar{q}_T}\right) \doteq 0.7 + 0.0032\,\bar{q}_T \tag{6.3}$$

as shown in Figure 36.

The numerical values given in equations (6.1a), (6.2a), and (6.3) represent the desired values in this program. Also, a mid c.g. which

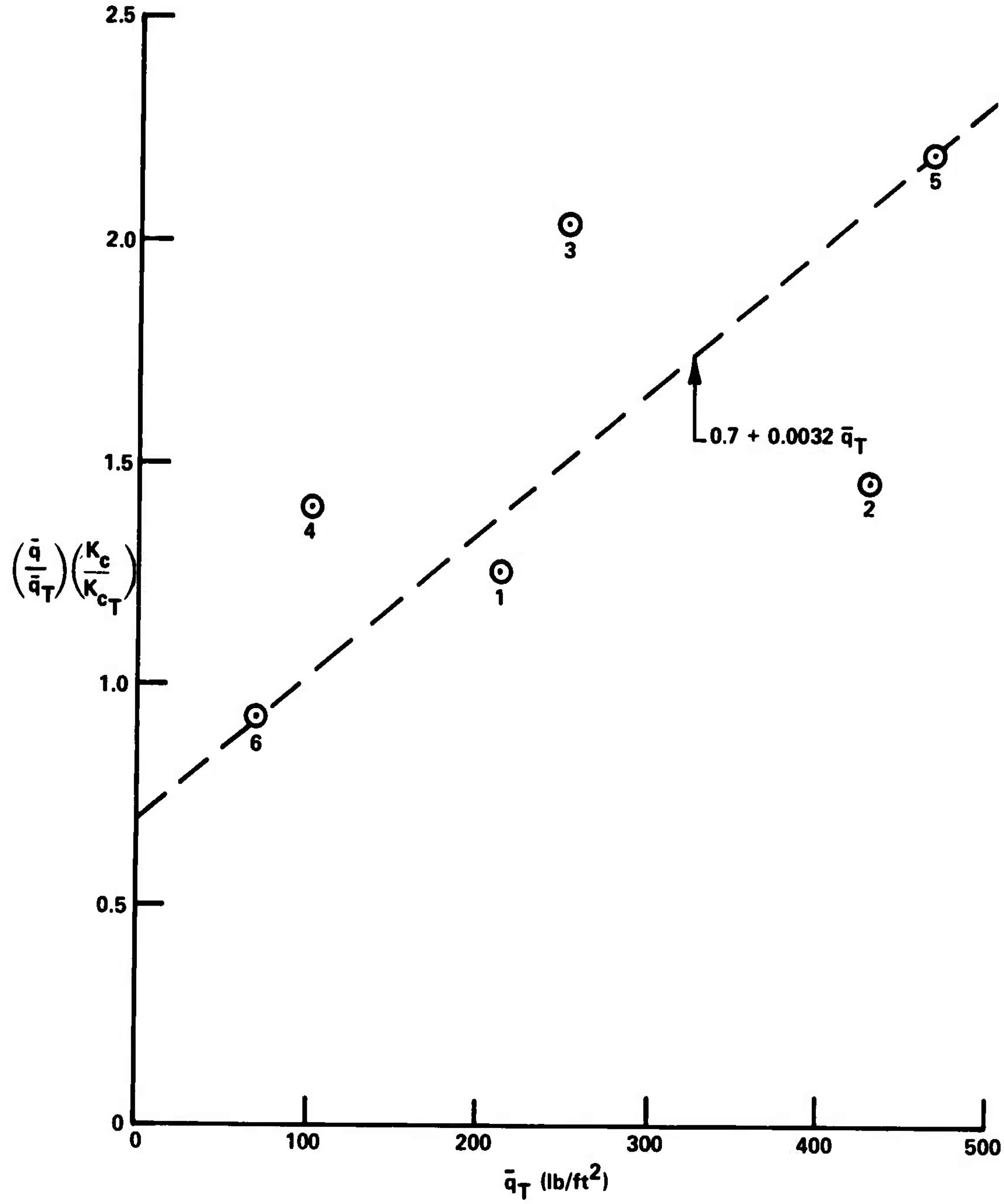

Figure 36 $\left(\frac{\bar{q}}{\bar{q}_T}\right)\left(\frac{K_c}{K_{c_T}}\right)$ VS $\bar{q}_T$

corresponds to $C_{m_\alpha} = -0.15$ at $\alpha = 0$ (see Figure 33) was chosen in this experiment. To determine the actual characteristics of the unaugmented simulated aircraft, an advanced digital identification computer program was used, as described in Appendix II, to extract the actual stability and control derivatives from the flight test data. This work is discussed further in the next section.

6.2.3 Identification of the Unaugmented Simulated Aircraft Characteristics From Flight Data

The longitudinal characteristics of the unaugmented simulated aircraft described in paragraphs 6.2.1 and 6.2.2 were used as the basic data in the design of the flight control systems, as discussed in the next section. It was important to identify the actual dynamic characteristics of the unaugmented simulated aircraft from the flight test data to correlate with the basic design data. Then valid conclusions may be drawn from the in-flight evaluation of the control systems designed. Furthermore, since the unaugmented aircraft was also evaluated in flight as a basic configuration, it is essential to use the identified parameters to correlate with the pilot comments and ratings.

A Calspan-developed advanced recursive identification technique (Ref. 11 and 12), known as the locally iterated, fixed-point smoothing technique, was used to identify the longitudinal stability and control derivatives of the short-period dynamics from the flight test data. A description of the equations and procedure employed is given in Appendix II.

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11. R.T.N. Chen, B. Eulrich, and J.V. Lebacqz, "Development of Advanced Techniques for the Identification of V/STOL Aircraft Stability and Control Parameters," Calspan Report No. BM-2820-F-1, August 1971.

12. R.T.N. Chen and B. Eulrich, "Parameter and Model Identification of Nonlinear Systems Using a Suboptimal Fixed-Point Smoothing Technique," JACC Preprint, pp. 731-740, August 1971.

Two flights (1402 and 1407) were flown to obtain the data records at the fixed operating points shown in Table IX for both the unaugmented simulated aircraft and the four augmented aircraft configurations discussed earlier. The capability for simulating the effects of a c.g. shift, shown in Figure 34, was only partially used in the in-flight evaluations. $\Delta c_{m_\alpha} = -0.10$ was used to simulate the separation of bombs during the ground attack Flight Phase, but no further c.g. shifts per se were exercised.

Table IX
DEFINITION OF NT-33A FLIGHT CONDITIONS (F.C.)

F.C.	Altitude (thousands of ft.)	Airspeed (KIAS)	Remarks
0	5,000	250	System engaged
1	12,000	250	Mach effect off
2'	5,000	330	Before bomb pickle
2	5,000	330	After bomb pickle
2a	25,000	210	Mach effect off
2b	25,000	220	Mach effect on
3	25,000	270	Mach effect on
4	25,000	170	Mach effect off
5 *	12,000	370	Mach effect on
5a*	12,000	330	Mach effect off
6 *	2,000	140	Gear down, flaps down Speed brake out

*Difficulties encountered in processing the raw flight data for parameter identification.

Control inputs used were steps and doublets. Figure 37 shows a typical response match of an identification run, and Table X shows the parameters identified. Figures 38 and 39 compare the parameters identified with the design data. As can be seen, some discrepancies exist between the design and identified data. The difference in n/α , as indicated in Figure 39, may be

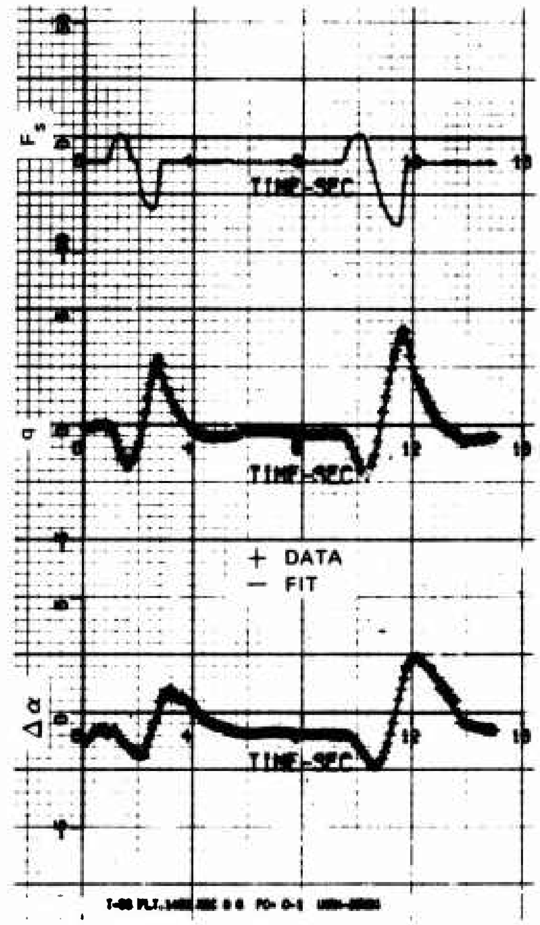


Figure 37 COMPUTER IDENTIFICATION, AIRCRAFT RESPONSE MATCH, F.C. = 0, CONFIGURATION II-1

Table X

PARAMETERS IDENTIFIED FROM FLIGHT TEST DATA FOR CONFIGURATION II-1

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	Z_α	Z_{F_S}	M'_α	M'_q	M'_{F_S} *
(DIM.)	–	–	1/sec	deg/sec-lb	1/sec^2	1/sec	deg/sec^2-lb
6	1402	0	-1.194	-0.00079	-0.832	-1.155	-0.374
54	↓	1	-1.312	-0.00553	-1.630	-0.988	-0.370
23	↓	2'	-2.017	0.00323	-5.188	-1.655	-0.791
51	↓	2	-2.087	0.00178	-8.822	-1.483	-0.788
24	1407	2b	-0.833	0.00160	-4.762	-0.709	-0.249
51	↓	3	-1.345	0.00832	-14.420	-0.818	-0.460

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	TRUE AIRSPEED V_T	n/α	F_S/n	ω_{SP}	ζ_{SP}
(DIM.)	–	–	ft/sec	g/rad	lb/g	rad/sec	–
6	1402	0	455	16.88	20.18	1.49	0.79
54	↓	1	505	20.66	21.94	1.71	0.67
23	↓	2'	625	37.58	16.44	2.92	0.63
51	↓	2	625	38.89	22.26	3.45	0.52
24	1407	2b	560	14.49	83.17	2.29	0.34
51	↓	3	685	28.59	67.64	3.94	0.27

*PRIME SIGNIFIES THAT THE EFFECT OF THE $M_{\dot{\alpha}}$ DERIVATIVE IS INCLUDED

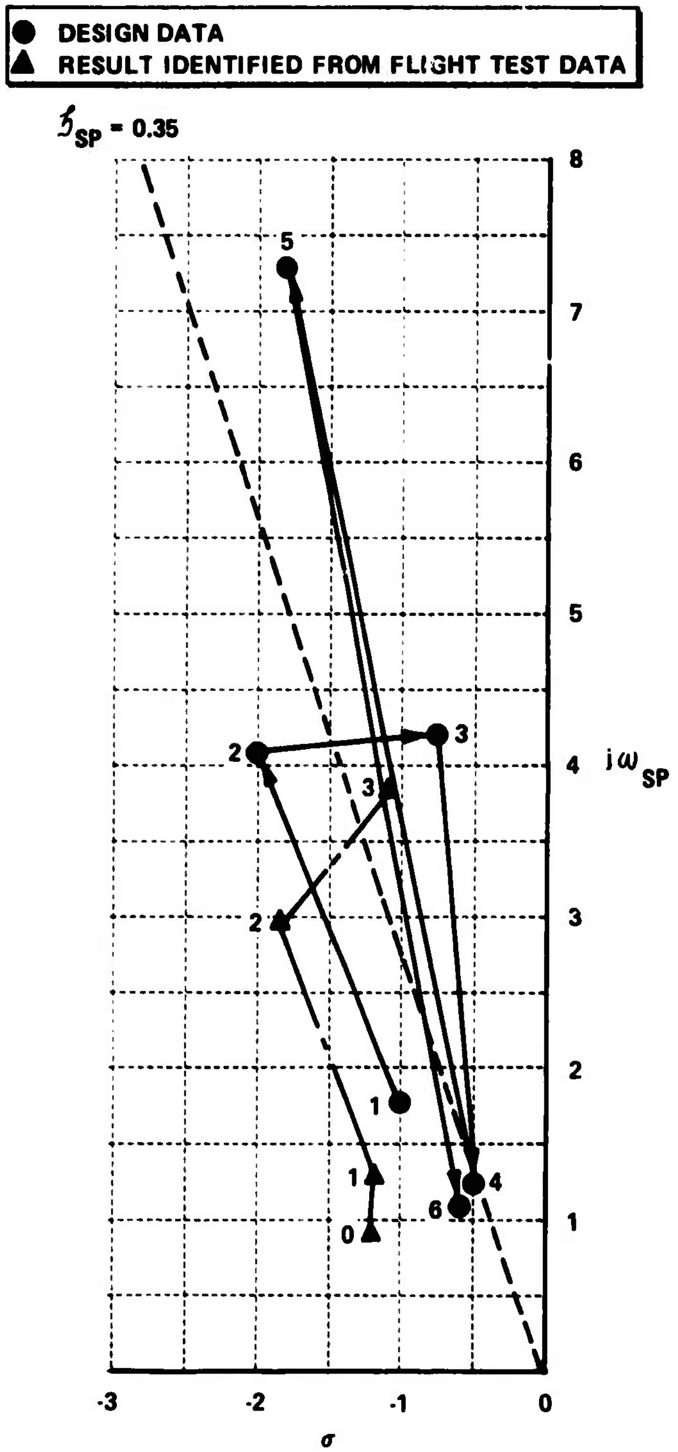


Figure 38 SHORT PERIOD ROOTS OF THE SIMULATED AIRCRAFT -- A COMPARISON OF THE DESIGN DATA AND IDENTIFIED DATA

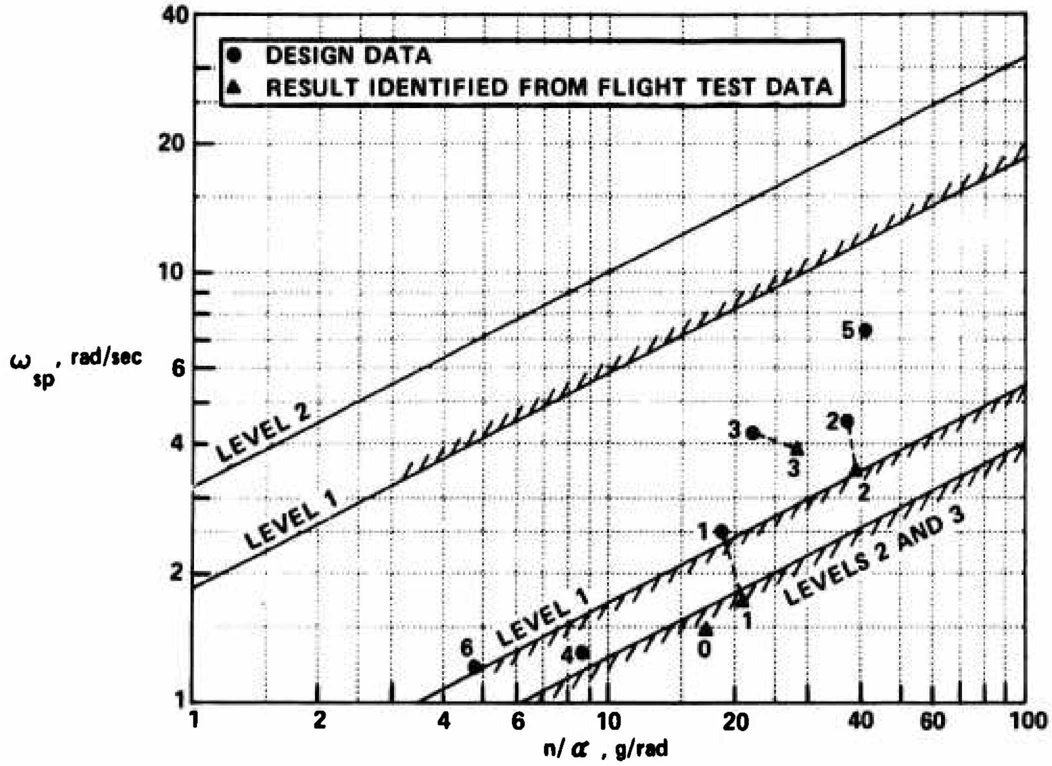


Figure 39 ω_{sp} vs n/α FOR THE UNAUGMENTED SIMULATED AIRCRAFT partly attributable to the difference in gross weight of the NT-33A; for the design data, a constant gross weight of 15,000 lb was assumed, whereas the actual weight changes as the fuel is consumed. Also, for the higher speed flight conditions, no compressibility corrections were applied to the M = 0 data used from Reference 6.

From Figures 38 and 39, it would be expected that the unaugmented simulated aircraft would have poor flying qualities, as was confirmed by in-flight evaluations, which are discussed in Section VII.

6.3 DESIGN OF FLIGHT CONTROL SYSTEMS

Four different flight control systems were designed around the unaugmented simulated aircraft, using combinations of various sensors for feedback. The following paragraphs discuss the philosophy, criteria, and procedure employed in designing these flight control systems. The final design configurations and the identification of the augmented aircraft from the flight test data are also presented.

6.3.1 Design Philosophy and Criteria

Since the longitudinal flight control systems considered here were restricted to only the pilot assisting, inner-loop, command augmentation system, manual control theory was used as the theoretical base from which to design these systems. The fundamental philosophy that guides the design of manual flight control systems may be stated in simple terms as follows:

(1) The closed-loop pilot-vehicle performance must meet certain performance measures, and

(2) To meet the performance measures, the pilot must be comfortable.

The first requirement is clearly necessary if the man-machine system is to achieve the performance level called for by the required missions or tasks. The comfort of the pilot in the second requirement may be manifested in the following conditions:

(A) The pilot is not required to provide compensation. Mathematically, the dynamic model of the pilot may be constrained, therefore, to an approximate expression

$$G_p(s) \doteq K_p e^{-\tau s} \tag{6.4}$$

$0.2 \leq \tau \leq 0.4$ second

(B) The pilot's maneuvering force must be within certain bounds and compatible, in the case of the longitudinal control system, with pitch sensitivity.

These requirements must be quantified before the design can commence. The quantitative requirements of (1) and (2) have been proposed by Neal and Smith (Ref. 1 and 4), as shown in Figures 40a and 40b.

In Figure 40b, the bandwidth $(BW)_{min}$ is defined as the frequency at which the phase angle $\measuredangle \frac{\theta}{\theta_c}$ is -90°. For fighter type aircraft, the bandwidth required depends on the Flight Phase. In Reference 4, it was proposed that the following minimum values are required for Level 1 flying qualities.

Flight Phase	$(BW)_{min}$, rad/sec
A	3
B	1.2
C	1.2

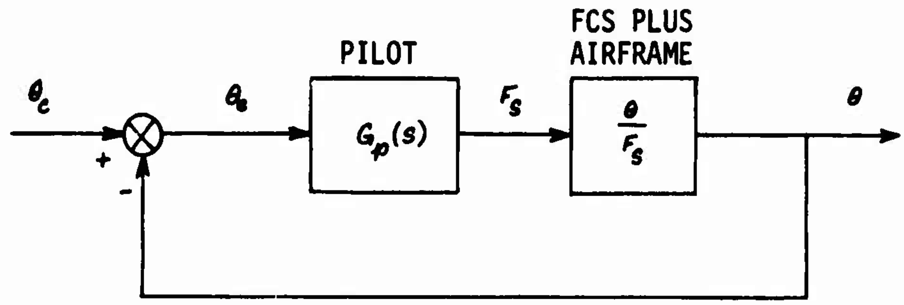
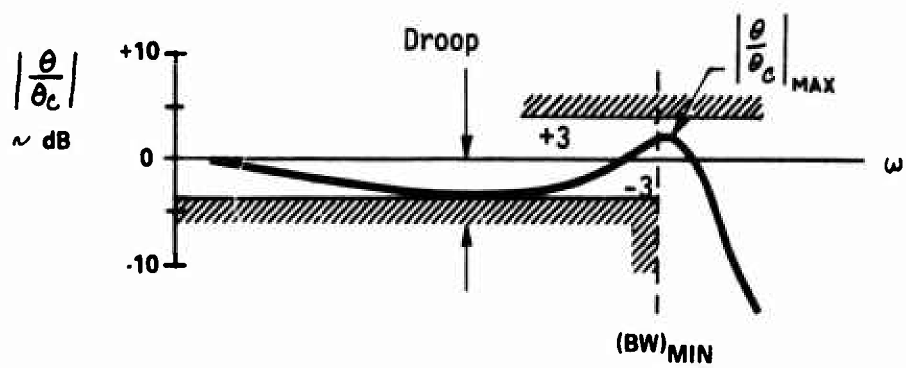


Figure 40a MATHEMATICAL MODEL OF PITCH ATTITUDE TRACKING (REF. 1)



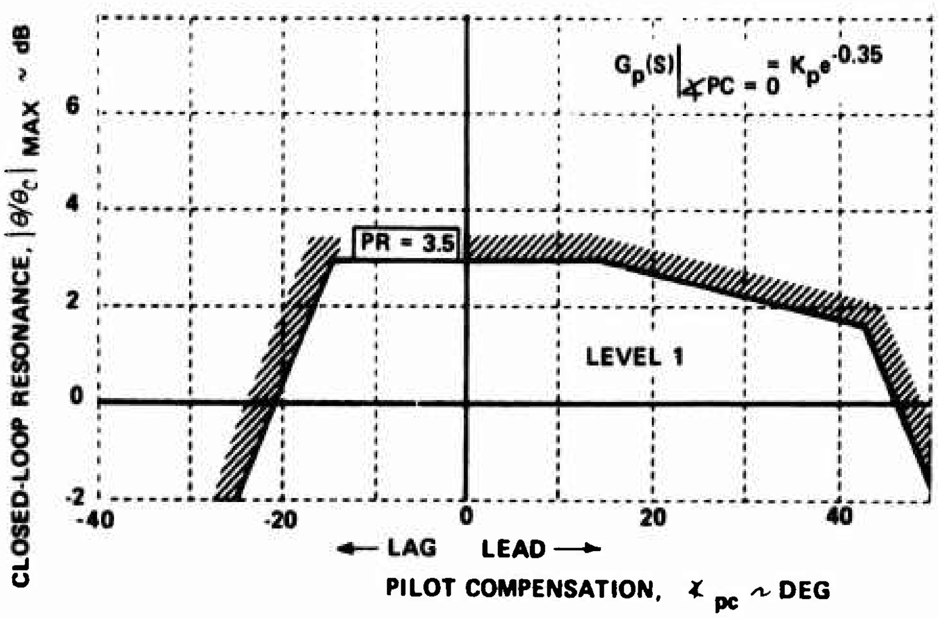


Figure 40b NEAL-SMITH PERFORMANCE CRITERION (REF. 1)

Quantitative requirements for (2) have also been proposed in Reference 4, as follows:

$$\frac{1}{\left|\frac{n_{cg}}{F}(j\omega)\right|} > \frac{14}{n_L - 1} \tag{6.5}$$

$$\omega \geq 1 \text{ rad/sec}$$

$$\left(\frac{F_s}{n}\right)\left(\left|\frac{\ddot{\theta}}{F_s}(j\omega)\right|\right)_{Max} < 3.6 \text{ rad/sec}^2/\text{g} \tag{6.6}$$

where n_L denotes the limit of load factor based on structural considerations.

6.3.2 Design Procedure

6.3.2.1 Preliminaries

Some preliminary steps were taken to simplify the design procedure based on the design criteria described in the preceding section. Using the transfer function, $\frac{\theta}{F_s}$,

$$\frac{\theta}{F_s} = \frac{M_{F_s}\left(s + \frac{1}{\tau_{\theta_2}}\right)}{s\left(s^2 + 2\zeta_{sp}\,\omega_{sp}\,s + \omega_{sp}^2\right)} \tag{6.7}$$

in the short-period dynamics, the ranges of $\hat{\zeta}_{sp}$ (particularly $\hat{\zeta}_{sp} > 0.7$) and $\hat{\omega}_{sp}$ that satisfy the closed-loop performance of Figure 40b were first determined by imposing the "comfortable" pilot model shown in Figure 40a.

$$G_p(s) = K_p e^{-0.3}(T_L s + 1), \quad 0 \leq T_L \leq 0.2 \tag{6.8}$$

where the range of T_L was so chosen that the Level 1 region of the Neal and Smith criterion was attained for all the Flight Phases (Figure 40b). This task was somewhat simplified by imposing the definition of the bandwidth, ω_B, yielding a necessary condition:

$$K_p M_{F_S} = \frac{2 \hat{\zeta}_{SP} \hat{\omega}_{SP} \hat{\omega}_B^2 \hat{A} - \omega_B (\hat{\omega}_{SP}^2 - \omega_B^2) \hat{B}}{\hat{A}^2 + \hat{B}^2} \qquad (6.9)$$

$$\hat{A} = \left[\frac{1}{\tau_{\theta_2}} - \omega_B^2 T_L\right] \cos(0.3\,\omega_B) + \omega_B \left[1 + \frac{T_L}{\tau_{\theta_2}}\right] \sin(0.3\,\omega_B)$$

$$\hat{B} = \omega_B \left[1 + \frac{T_L}{\tau_{\theta_2}}\right] \cos(0.3\,\omega_B) - \left[\frac{1}{\tau_{\theta_2}} - \omega_B^2 T_L\right] \sin(0.3\,\omega_B)$$

Figures 41a through 41d show some sample examples of the closed-loop Bode plots using equation (6.9). Note that these cases meet the Level 1 requirements of MIL-F-8785B(ASG).

The results of this preliminary step can be stated as follows: For a constant-speed dynamic model of the unaugmented aircraft, the right-hand portion of the Level 1 region in Figure 40b (which corresponds to $T_L = 0$ to $T_L = 0.2$ sec) maps into the lower two-thirds portion of the Level 1 region in Figure 39; the lower limit of the Level 1 region in Figure 39 corresponds to $T_L = 0.2$ sec. A line for $T_L = 0$ would be approximately two-thirds the distance between the lower Level 1 boundary and the upper Level 1 boundary in Figure 39. The desirable range of the damping ratio was found to be $\zeta \geq 0.7$.

No attempts were made to correlate the left-hand portion of the Level 1 region in Figure 40b (which requires some lag compensation by the pilot) with the Level 1 region in Figure 39.

This preliminary step thus simplifies the procedure of longitudinal control system design, if an attempt is made not to increase of the order of the augmented aircraft. The designer may, for instance, choose $\zeta_{SP} \geq 0.7$ and directly use the criterion required in Figure 39. The resulting augmented aircraft would then satisfy the pilot-vehicle closed-loop performance requirements. Furthermore, by choosing $\zeta_{SP} \geq 0.7$, the condition shown by equation (6.6) would also be automatically satisfied.

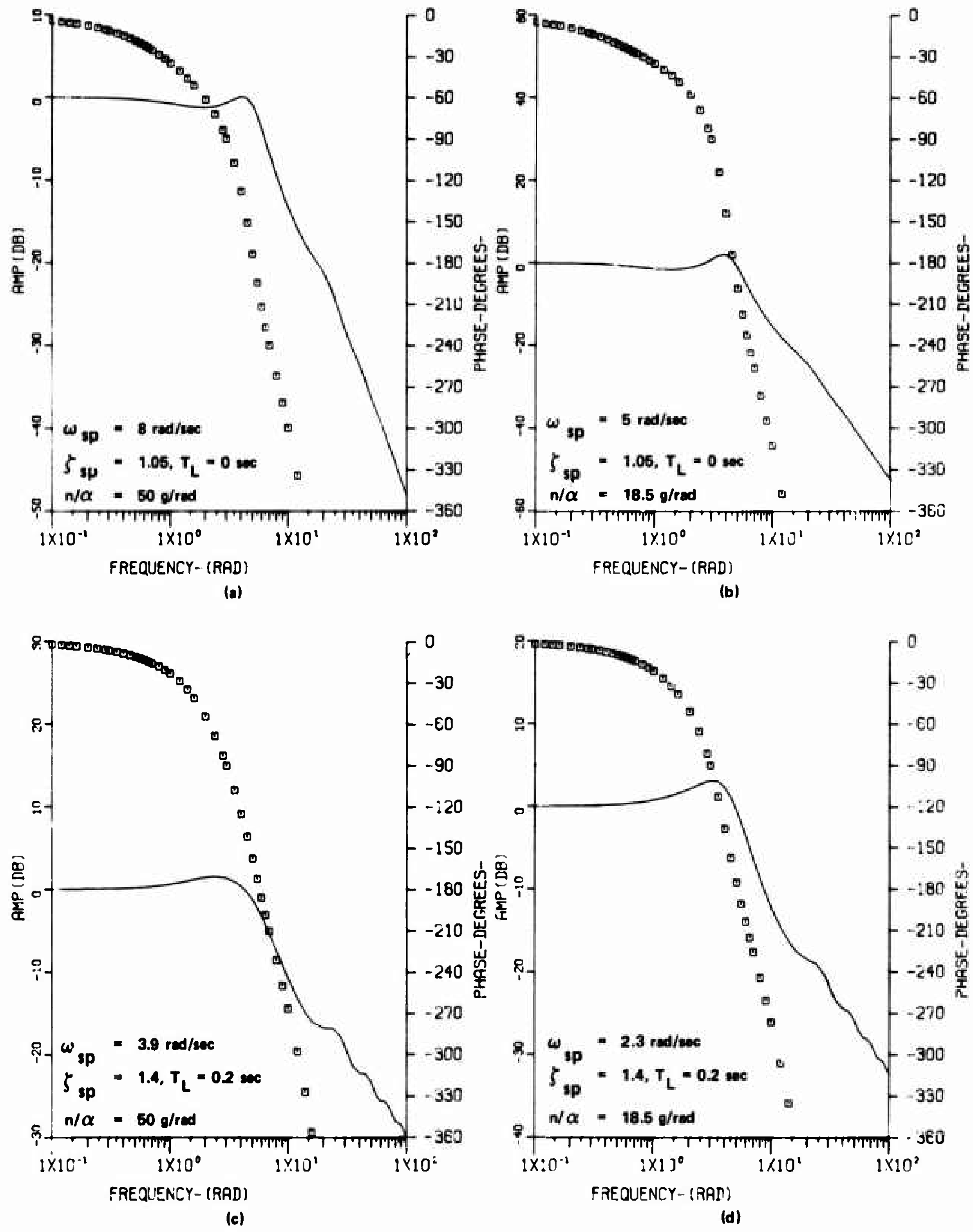


Figure 41 CLOSED-LOOP BODE PLOTS USING EQUATION 6.9

To meet the requirement given by equation (6.5), another preliminary step was taken to examine the effect of feedback and feedforward on the pilot's maneuvering force. The feedback variables considered were q, n_{z_p}, and α. The use of the first two variables is somewhat standard; their effect on the dynamic characteristics of the augmented aircraft has been discussed at length elsewhere (see, for instance, Reference 13). The use of α has been shown to be very desirable, especially in improving the flying qualities of fighter aircraft in high α operations (References 3, 14, 15).

Figure 42 is a block diagram of the flight control system configuration considered and evaluated in this program.

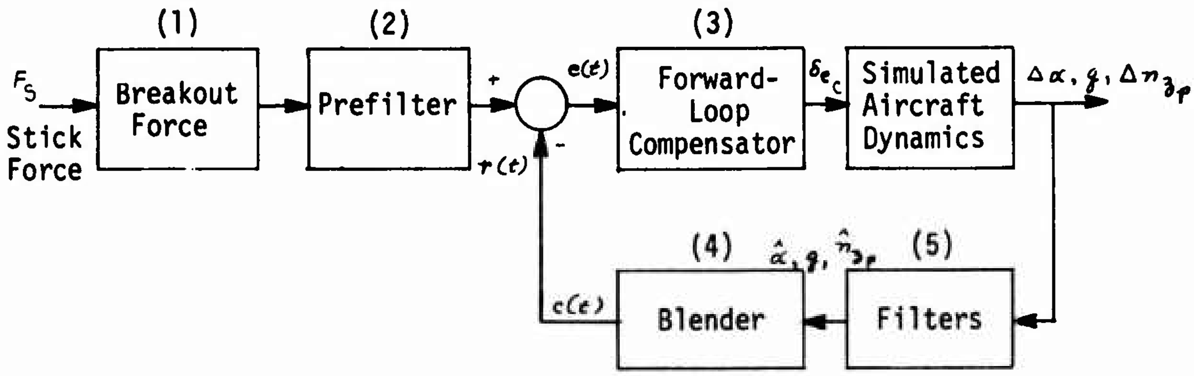


Figure 42 BLOCK DIAGRAM OF FLIGHT CONTROL SYSTEM CONFIGURATION FOR EVALUATION

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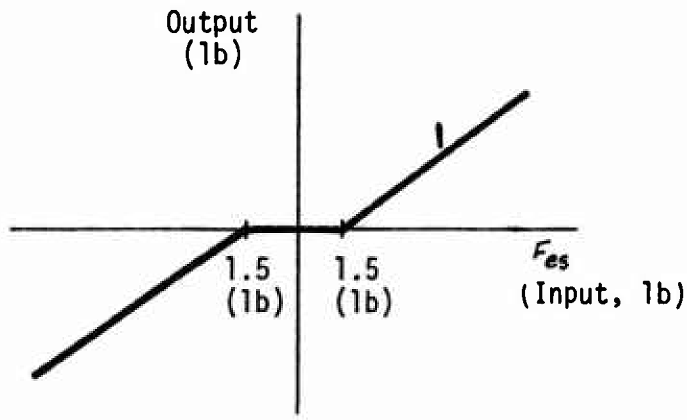
13. J.N. Ball and E.G. Rynaski, "Longitudinal Flight Control for Military Aircraft - A Study of Requirements and Design Concepts," Calspan Report No. ID-1757-F-1, October 1963.

14. D.P. Rubertus, "Twead Control Augmented System," Paper presented at the N.A.E.C., Dayton, Ohio, 15-17 May 1972.

15. R.T.N. Chen, et al., "Development and Evaluation of an Automatic Departure Prevention System and Stall Inhibitor for Fighter Aircraft," Calspan Report No. AK-5112-F-1 (AFFDL-TR-73-29), April 1973.

Some pertinent features of the flight control system components were as follows:

(1) Breakout Force



The breakout force and the force gradient were variable and the final values used were set to ±1.5 lb and 1 lb respectively.

(2) Prefilter

The first-order prefilter had a transfer function of the form:

$$\frac{F_{ES\,OUT}}{F_{ES\,IN}} = \frac{\omega_c}{s + \omega_c} \tag{6.10}$$

where ω_c was ground adjustable in the range $1 \leq \omega_c \leq 10$ rad/sec. The prefilter could also be by-passed.

(3) Forward Loop Compensator

The forward loop compensator was of the form:

$$K\left(1 + K_i \frac{1}{s}\right) \tag{6.11}$$

providing proportion plus integral control in the forward loop. In this mechanization, K was a function of dynamic pressure, $\bar{q}$, and K_i was a constant which could be set to zero.

(4) Blender

$$c(t) = K_n \hat{n}_{z_p} + K_q q + K_\alpha \hat{\alpha} \tag{6.12}$$

K_n, K_q, and K_α were constants (but adjustable and could be set to zero) and $\hat{n}_z$ and $\hat{\alpha}$ are defined by equations 6.13 and 6.14.

(5) Filters

The filters were of the first-order form

$$\frac{\hat{\alpha}}{\alpha}(s) = \frac{\omega_\alpha}{s + \omega_\alpha} \tag{6.13}$$

$$\frac{\hat{n}_z}{n_z}(s) = \frac{\omega_{n_z}}{s + \omega_{n_z}} \tag{6.14}$$

where ω_α and ω_{n_z} were adjustable, but were set at 15 rad/sec for all evaluation flights as discussed on p. 117.

With the configuration considered, it can readily be shown that the steady-state value of $\frac{n_{cg}}{F_s}$ is given by

$$\left.\frac{n_{cg}}{F_s}\right|_{ss} = \frac{V}{g} \frac{\frac{1}{T_{\theta_2}} KM_F}{\omega_{SP}^2 + KM_F K_q \left[\frac{K_\alpha}{K_q} + \frac{1}{T_{\theta_2}}\left(1 + \frac{V}{g}\frac{K_n}{K_q}\right)\right]} \qquad K_i = 0 \tag{6.15}$$

$$= \frac{V}{g} \frac{1}{K_q + \frac{V}{g} K_n} \qquad K_i \neq 0 \tag{6.16}$$

which indicates that with integral control in the forward loop the steady-state stick force per g is a function of only the feedback gains K_q and K_n, and the true airspeed. The integral control was included as an additional configuration in this in-flight investigation because of its desirable "autotrim" feature as experienced in the Twead program (Ref. 14). It should be pointed out, however, that to achieve the autotrim capability, the α feedback must be deleted. Otherwise, an increase in airspeed would result in a nose-up pitch rate, and the stick would have to be pushed forward to re-trim the airplane.

6.3.2.2 Design Procedure for $K_i = 0$

Three configurations as described earlier in paragraph 6.1.1 were designed around the unaugmented simulated aircraft (Configuration II-1) without using integral control in the forward loop. In designing these systems an attempt was made to not increase the order of the system through a direct feedback of the airplane response variables α, q, and n_{z_p}, where n_{z_p} is the normal acceleration near the pilot station. As a result, the useful simplifications discussed above became directly applicable. The design procedure used was as follows:

(1) Select a desired range for short period undamped natural frequency $\hat{\omega}_{sp}$ according to flight condition (designated here by n/α) as shown in Figure 43. Note that the flight conditions 3 and 5 were in supersonic flight and their $\hat{\omega}_{sp}$ range was selected differently from that for the subsonic flight conditions because the ω_{sp} of the unaugmented simulated airplane was within the desired range. Sufficient margins from the Level 1 boundaries were provided to allow for possible uncertainty in the mechanization of the unaugmented simulated aircraft and the flight control systems.

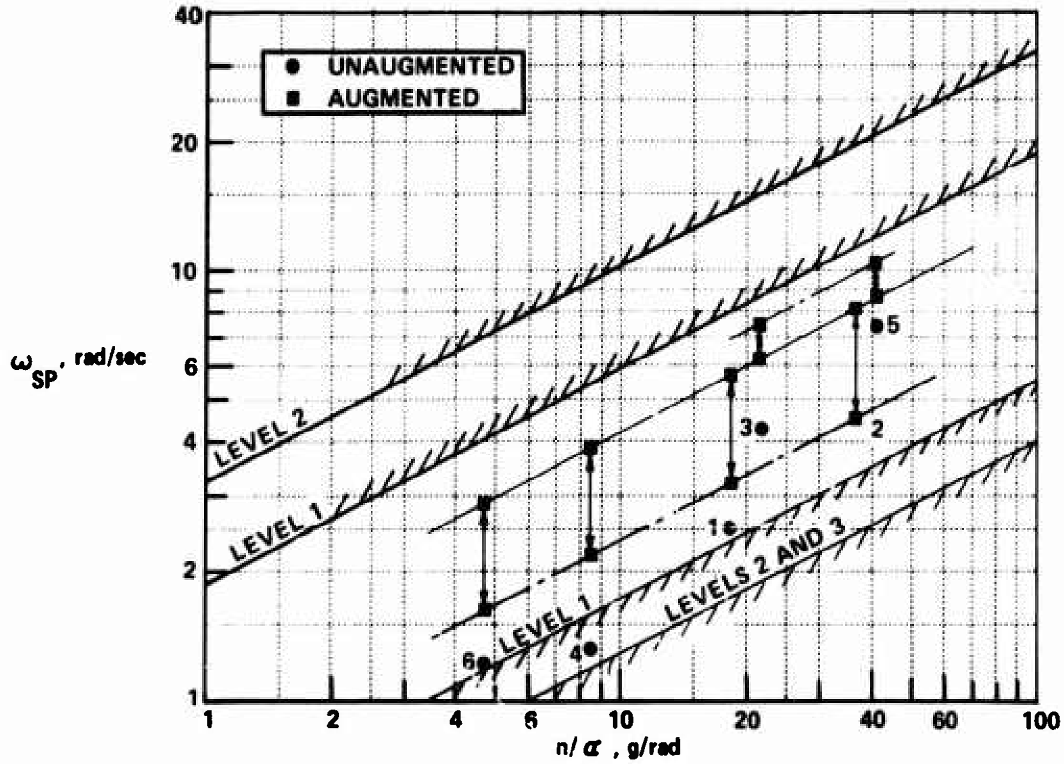


Figure 43 DESIGNED RANGE OF ω_{SP} vs n/α

(2) Calculate, at each flight condition, the gains K_α, K_q, K_n, and K for both the lower and the upper value of $\hat{\omega}_{sp}$, using the following set of equations. See Appendix IV.

$$K_o \triangleq \frac{\ell}{g}\frac{K_n}{K_q} = \frac{\left(\hat{\omega}_{sp}^2 - \omega_{sp}^2\right) + \left(2\zeta_{sp}\omega_{sp} - 2\hat{\zeta}_{sp}\hat{\omega}_{sp}\right)\left(\frac{K_\alpha}{K_q} + \frac{1}{T_{\theta_2}}\right)}{\left(\hat{\omega}_{sp}^2 - \omega_{sp}^2\right)\left(2\hat{\zeta}_{sp}\hat{\omega}_{sp} - \frac{1}{T_{\theta_2}}\right) + \left(2\zeta_{sp}\omega_{sp} - 2\hat{\zeta}\hat{\omega}_{sp}\right)\left(\hat{\omega}_{sp}^2 - \frac{V}{\ell}\frac{1}{T_{\theta_2}}\right)} \tag{6.17a}$$

$$\overline{KM}_{\delta_e} K_q = \frac{2\zeta_{sp}\omega_{sp} - 2\hat{\zeta}_{so}\hat{\omega}_{sp}}{\left(2\hat{\zeta}_{sp}\hat{\omega}_{sp} - \frac{1}{T_{\theta_2}}\right)K_o - 1} \tag{6.17b}$$

$$\overline{KM}_{\delta_e} = \frac{1}{\frac{V}{g}\frac{1}{T_{\theta_2}}} \; \frac{\hat{\omega}_{sp}^2}{N}\left(1 + \overline{KM}_{\delta_e} K_q K_o\right) \tag{6.17c}$$

where N is the desired stick force per g, and K is the forward loop gain. In this program, N was set at 5 lb/g and the desired short-period damping ratio, $\hat{\zeta}_{sp}$, set at 1. For configuration II-3, it is obvious that the solution is not unique (three equations for four parameters). Several values of the ratio K_α/K_q may be tried and then one value judiciously selected that would yield proper gain levels and require no use of positive feedback.

(3) Schedule the gains. For sake of easy mechanization, the feedback gains were held constant in this program. The forward loop gain K was, however, scheduled as a function of the dynamic pressure. Figures 44(a) and 44(b) show an example of gain scheduling for configuration II-4.

(4) Check to see if all the design requirements are met using the scheduled gains. If not, go back to step (3).

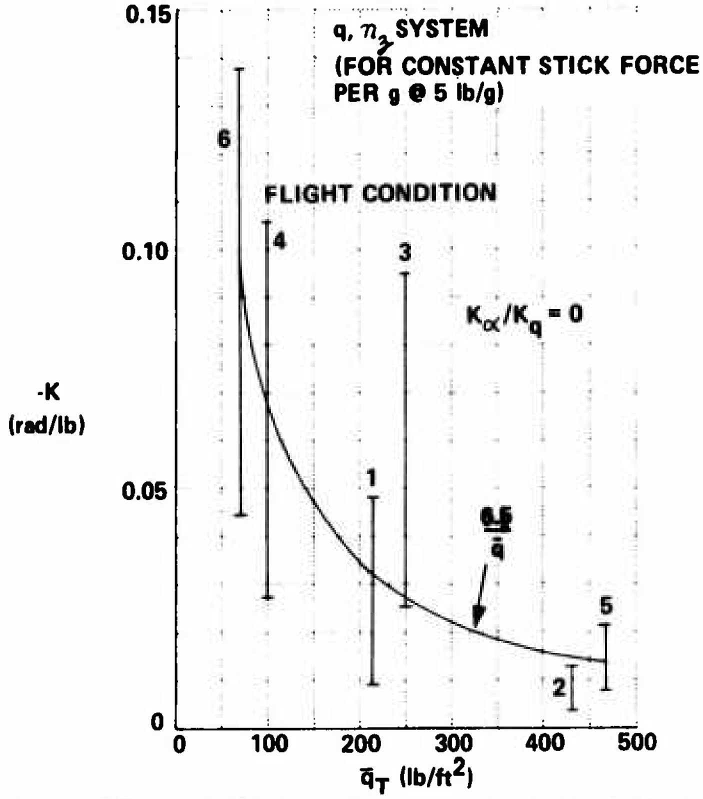


Figure 44a GAIN SCHEDULE OF THE FORWARD LOOP GAIN FOR CONFIGURATION II-4

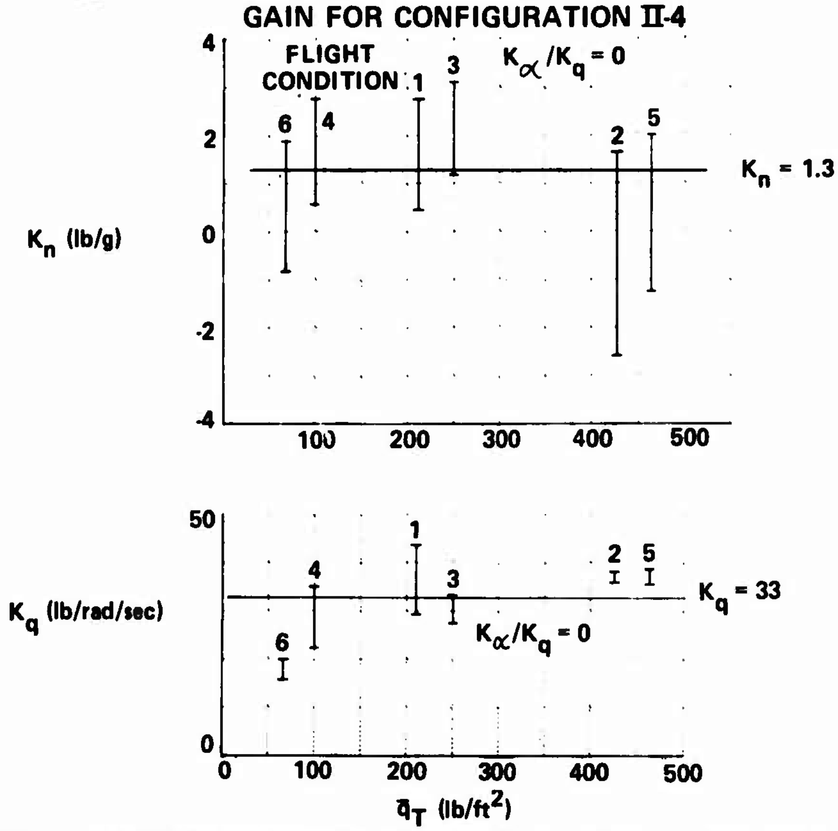


Figure 44b RANGES OF FEEDBACK GAINS, K_n AND K_q AT VARIOUS FLIGHT CONDITIONS FOR CONFIGURATION II-4

6.3.2.3 Design Procedure for $K_i \neq 0$ (Configuration II-5)

The purpose of designing the configuration, which utilizes a proportional plus integral control in the forward loop and a prefilter to shape the pilot's force input, was to compare directly with Configuration II-4. Recall that Configuration II-4 used neither the integral action in the forward loop nor the pilot's prefilter, although the same feedback signals; i.e., n_{z_p} and q, were employed. With this preselected configuration, the open-loop transfer function for Configuration II-5 becomes (see Figure 42 with the α feedback and sensor filters deleted):

$$G(s) \triangleq \frac{\theta}{F_s}(s) = \frac{K_t (s + K_i)\left(s + \frac{1}{T_{\theta_2}}\right)}{s(s+\omega_c)(s^3 + a_2 s^2 + a_1 s + a_0)} \tag{6.18}$$

where

$$K_t = \frac{\omega_c \hat{K}}{1 + \hat{K} K_n \frac{\ell}{g}} \tag{6.19a}$$

$$a_0 = \frac{\hat{K} K_n \left(\frac{\ell}{g}\right) K_i \omega_1^2}{1 + \hat{K} K_n \frac{\ell}{g}} \tag{6.19b}$$

$$a_1 = \frac{\omega_{sp}^2 + \hat{K} K_n \frac{\ell}{g}(\omega_1^2 + 2\zeta_1 \omega_1 K_i)}{1 + \hat{K} K_n \frac{\ell}{g}} \tag{6.19c}$$

$$a_2 = \frac{2\zeta_{sp}\omega_{sp} + \hat{K} K_n \frac{\ell}{g}(K_i + 2\zeta_1\omega_1)}{1 + \hat{K} K_n \frac{\ell}{g}} \tag{6.19d}$$

$$\hat{K} \triangleq M_{\delta_e} K \tag{6.19e}$$

$$\omega_1^2 = \frac{\frac{1}{T_{\theta_2}}\left(1 + \frac{V}{g}\frac{K_n}{K_q}\right)}{\frac{K_n}{K_q}\left(\frac{\ell}{g}\right)} \tag{6.19f}$$

$$2\zeta_1\omega_1 = \frac{1 + \frac{1}{T_{\theta_2}}\left(\frac{K_n}{K_q}\right)\left(\frac{\ell}{g}\right)}{\frac{K_n}{K_q}\left(\frac{\ell}{g}\right)} \tag{6.19g}$$

The procedure utilized in determining the five parameters ω_c, K, K_i, K_n and K_q in Eqs. (6.18) and (6.19) was essentially trial and error using the following steps.

(1) Choose several values of K_q/K_n and use equations (6.16) to calculate K_n necessary to achieve the desired stick force per g for all the flight conditions. In this program the selection of candidate values of K_q/K_n was guided by the value used in Configuration II-4.

(2) Choose a constant K_n for each value of K_q/K_n that will achieve the minimum stick force per g requirement (N = 5 lb/g in this program) for all the flight conditions. Thus, for each level of K_q/K_n, a pair (K_n, K_q) is obtained in order to achieve a configuration with constant feedback gains.

(3) For each pair of (K_n, K_q) obtained in step (2), choose a value of ω_c and obtain a pair of forward loop gains K and K_i that satisfy the closed-loop performance requirement at each flight condition. This step was simplified somewhat by imposing the the definition of the bandwidth, ω_B, in equations (6.8) and (6.18), yielding

$$K_P K_t = \frac{-(CA + DB)}{A^2 + B^2} \tag{6.20}$$

where

$$A = T_L \omega_B^4 - \omega_B^2 \left[(b_1 - 6.67) + T_L \left(b_0 - 6.67 b_1 \right) \right] - 6.67 b_0$$

$$B = -\omega_B^3 \left[1 + T_L (b_1 - 6.67) \right] + \omega_B \left[(b_0 - 6.67 b_1) - 6.67 b_0 T_L \right]$$

$$C = \omega_B^6 - \omega_B^4 \left[a_1 + a_2 (6.67 + \omega_c) \right] + \omega_B^2 \left[a_0 (6.67 + \omega_c) + 6.67 a_1 \omega_c \right]$$

$$D = -\omega_B^5 (a_0 + 6.67 + \omega_c) + \omega_B^3 \left[a_0 + a_1 (6.67 + \omega_c) \right] - \omega_B (6.67 \omega_c a_0)$$

$$b_0 = \frac{1}{T_{\theta_2}} K_i$$

$$b_1 = K_i + \frac{1}{T_{\theta_2}}$$

Note that this step is analogous to that used in obtaining the required $\hat{\zeta}_{sp}$ and $\hat{\omega}_{sp}$ using equation (6.9) as discussed earlier in the preliminary steps. In obtaining equations (6.20), however, a Padé approximation was used for the delay term $e^{-0.3s}$, i.e.

$$e^{-0.3s} = -\frac{s - 6.67}{s + 6.67} \tag{6.21}$$

(4) Repeat step (3) using other values of ω_c as required. In this program two values of ω_c, 4 and 10 rad/sec were tried.

(5) Repeat step (3) using other pair of (K_η, K_q) obtained in step (2). The above steps will result in a set of candidate systems, each with the desired set of parameters ω_c, K, K_i, K_η and K_q that satisfy the closed-loop performance and stick force per g requirements.

(6) Check the pitch sensitivity requirement given by (6.6) for the candidate systems obtained.

6.3.3 Designed Longitudinal SCAS for In-Flight Evaluation

The procedure for designing the longitudinal stability and control augmentation system (SCAS) discussed in the preceding section was used to design the four SCAS configurations around the unaugmented simulated aircraft. This procedure was a typical classical frequency domain method. A modern optimal control method similar to that used in Reference 16, however, should also be investigated. The design parameters are shown in the following table:

16. R.T.N. Chen, "A New Analytic Approach to Flight Director Design," Calspan X-22A TM No. 66, 25 September 1973.

Table XI
SCAS DESIGN PARAMETER VALUES

Configuration	II-2	II-3	II-4	II-5
K_α (lb/rad)	20	10	--	--
K_q (lb/rad/sec)	33	33	33	49
K_n (lb/g)	--	0.52	1.30	1.90
K (rad/lb)	$\frac{5.5}{\bar{q}}$	$\frac{6.0}{\bar{q}}$	$\frac{7.5}{\bar{q}}$	$\frac{5.5}{\bar{q}}$
K_i (rad/sec)	--	--	--	0.4
ω_c (rad/sec)	--	--	--	4

In the early functional check flights without incorporating the sensor filters, it was found that there was high frequency noise ($\approx$ 20 cps) contaminated in the n_{z_p} signal. In all the evaluation flights, the first-order sensor filters were introduced with their corner frequency ω_α and ω_{n_z} (see 6.13 and 6.14) set at 15 rad/sec, which was in a high enough frequency range as not to severely affect the designed SCAS.

Flight data of these augmented configurations were taken following the evaluation flights for parameter identification and correlation with the pilot ratings and comments. This is discussed in the next section.

6.3.4 Identification of the Augmented Aircraft Characteristics from Flight Data

The stability and control derivatives in the short-period dynamic equations were identified from the flight test data for the four augmented configurations at various flight conditions. The equations and identification technique used were the same as those used for the simulated unaugmented aircraft discussed earlier in paragraph 6.2.3. More details can be found in Appendix II. The identified stability and control derivatives were then used to calculate ζ_{SP}, ω_{SP}, n/α and F_S/n, the stick force per g. These identified parameters were given in Tables XII through XV for Configurations II-2

Table XII
PARAMETERS IDENTIFIED FROM FLIGHT TEST DATA
FOR CONFIGURATION II-2 (α , q SYSTEM)

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	Z_α	Z_{F_S}	M'_α	M'_q	M'_{F_S}
(DIM.)	–	–	1/sec	deg/sec-lb	$1/sec^2$	1/sec	deg/sec^2-lb
10	1402	0	-1.271	-0.0056	-1.563	-6.553	-2.310
57	↓	1	-1.274	-0.0093	-2.043	-5.676	-2.102
26	↓	2′	-1.865	0.0003	-4.366	-7.731	-2.550
48	↓	2	-2.028	-0.0018	-6.471	-7.157	-2.416
20	1407	2a	-0.854	-0.0030	-0.890	-0.538	-2.011
27	↓	2b	-0.900	-0.0026	-5.681	-5.359	-2.058
48	↓	3	-1.306	0.0064	-15.480	-6.441	-2.409
57	↓	4	-0.701	0.0002	0.995	-6.887	-2.594

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	TRUE AIRSPEED, V_T	n/α	F_S/n	ω_{SP}	ζ_{SP}
(DIM.)	–	–	ft/sec	g/rad	lb/g	rad/sec	–
10	1402	0	455	17.96	13.70	3.15	1.24
57	↓	1	505	20.06	12.64	3.05	1.14
26	↓	2′	625	34.75	12.18	4.34	1.11
48	↓	2	625	37.79	13.17	4.58	1.00
20	1407	2a	530	14.06	11.11	2.34	1.33
27	↓	2b	560	15.66	18.66	3.24	0.97
48	↓	3	685	27.77	20.48	4.89	0.80
57	↓	4	420	9.35	6.05	1.60	1.94

Table XIII
PARAMETERS IDENTIFIED FROM FLIGHT TEST DATA
FOR CONFIGURATION II-3 (α, q, n_z SYSTEM)

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	Z_α	Z_{F_S}	M'_α	M'_q	M'_{F_S}
(DIM.)	–	–	1/sec	deg/sec-lb	1/sec^2	1/sec	deg/sec^2-lb
13	1402	0	-1.227	-0.0046	1.549	-7.046	-2.554
59	↓	1	-1.267	-0.0060	0.581	-6.146	-2.278
29	↓	2'	-1.885	-0.0010	0.073	-7.932	-2.687
44	↓	2	-1.994	0.0068	-3.304	-8.393	-2.766
11	1407	2a	-0.823	0.0003	1.174	-6.414	-2.472
30	↓	2b	-0.877	0.0019	-3.584	-5.877	-2.182
45	↓	3	-1.333	0.0083	-12.200	-6.760	-2.500
60	↓	4	-0.697	0.0029	1.692	-6.583	-2.494
69	1402	5a	-2.126	-0.0116	-4.764	-7.917	-2.628

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	TRUE AIRSPEED, V_T	n/α	F_S/n	ω_{SP}	ζ_{SP}
(DIM.)	–	–	ft/sec	g/rad	lb/g	rad/sec	–
13	1402	0	455	17.34	9.16	2.66	1.55
59	↓	1	505	19.95	9.05	2.68	1.38
29	↓	2'	625	35.12	9.05	3.86	1.27
44	↓	2	625	37.15	11.19	4.48	1.16
11	1407	2a	530	13.55	7.05	2.03	1.79
30	↓	2b	560	15.26	15.07	2.96	1.14
45	↓	3	685	28.34	17.19	4.61	0.88
60	↓	4	420	9.29	7.17	1.70	2.14
69	1402	5a	475	31.36	15.01	4.65	1.08

Table XIV
PARAMETERS IDENTIFIED FROM FLIGHT TEST DATA
FOR CONFIGURATION II-4 (n_y, q SYSTEM)

RUN NO. (DIM.)	FLIGHT NO. –	FLIGHT CONDITION –	Z_α 1/sec	Z_{F_S} deg/sec-lb	M'_α 1/sec^2	M'_q 1/sec	M'_{F_S} deg/sec^2-lb
16	1402	0	-1.230	-0.0040	5.526	-7.224	-2.616
61	↓	1	-1.309	-0.0035	3.299	-6.782	-2.535
32		2′	-2.001	0.0057	5.949	-8.597	-2.891
41		2	-2.013	0.0011	4.950	-9.254	-2.947
33	1407	2b	-0.913	0.0022	-0.726	-6.570	-2.446
42	↓	3	-1.347	0.0100	-6.149	-7.543	-2.725
67	1402	5a	-2.138	0.0001	4.209	-8.552	-2.775

RUN NO. (DIM.)	FLIGHT NO. –	FLIGHT CONDITION –	TRUE AIRPSEED, V_T ft/sec	n/α g/rad	F_S/n lb/g	ω_{SP} rad/sec	ζ_{SP} –
16	1402	0	455	17.38	4.22	1.83	2.31
61	↓	1	505	20.61	6.11	2.36	1.71
32		2′	625	37.28	6.00	3.35	1.58
41		2	625	37.51	7.10	3.70	1.52
33	1407	2b	560	15.88	9.97	2.60	1.44
42	↓	3	685	28.63	11.99	4.04	1.10
67	1402	5a	475	31.54	9.21	3.75	1.42

Table XV
CONFIGURATION II-5, PARAMETER IDENTIFIED FROM FLIGHT TEST DATA – PREFILTER NOT INCLUDED

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	Z_α	Z_{F_S}	M'_α	M'_q	M'_{F_S}
(DIM.)	—	—	1/sec	deg/sec-lb	$1/sec^2$	1/sec	deg/sec^2-lb
19	1402	0	-1.259	-0.0052	8.578	-10.17	-2.606
63	↓	1	-1.394	-0.0022	10.250	-12.81	-3.101
35	↓	2'	-1.905	0.0066	18.670	-15.30	-3.568
38	↓	2	-1.886	0.0098	15.360	-13.96	-3.156
65	↓	5a	-2.547	0.0009	25.620	-17.49	-3.851
17	1407	2a	-0.847	-0.0049	6.187	-11.29	-2.936
36	↓	2b	-0.953	0.0047	2.312	-12.80	-3.074
39	↓	3	-1.157	0.0167	1.214	-11.73	-2.751
69	↓	6	-0.857	-0.0045	5.082	-10.95	-2.808

RUN NO.	FLIGHT NO.	FLIGHT CONDITION	TRUE AIRSPEED	n/α	F_S/n	ω_{sp}	ζ_{sp}
(DIM.)	—	—	ft/sec	g/rad	lb/g	rad/sec	—
19	1402	0	455	17.79	5.24	2.06	2.78
63	↓	1	505	21.95	6.41	2.76	2.58
35	↓	2'	625	35.50	4.75	3.24	2.66
38	↓	2	625	35.14	5.66	3.31	2.39
65	↓	5a	475	37.57	7.49	4.35	2.30
17	1407	2a	530	13.94	4.74	1.84	3 31
36	↓	2b	560	16.58	11.08	3.14	2.19
39	↓	3	685	24.60	10.49	3.52	1.83
69	↓	6	245	6.52	13.46	2.07	2.85

through II-5, respectively. Since the form of the transfer functions for the first three configurations are not significantly affected by the control system, the values of ω_{SP} vs n/α were plotted, respectively, in Figures 45 through 47. Because the form of the transfer function of Configuration II-5 is of higher order, ω_{SP} vs n/α criterion is not directly applicable for this configuration and hence these parameters are not plotted.

From these tables and figures, the following observations may be made:

(1) The damping ratios identified for all the configurations are above 0.8 at all the flight conditions. Therefore, the ω_{SP} vs n/α criterion and the F_S/n are all the requirements that the first three augmented configurations (II-2 through II-4) must meet (see paragraph 6.3.2). As far as the flight conditions at which the parameters were identified, all the Level 1 requirements were met, with one exception: flight conditions 0 and 1 in Configuration II-4 were slightly outside the Level 1 bounds.

(2) The Z_α values identified for all the configurations are, as expected, very close at the same flight condition.

(3) Comparing Figures 45 through 47 with the design data, on Figure 43 the ω_{SP} identified seems to be uniformly smaller than that for the design data. This same trend was also seen in the unagumented simulated aircraft, as mentioned earlier (see Figure 39). One possible reason for such discrepancies can be attributable to c.g. location; the c.g. location of the unaugmented aircraft may have been set inadvertently more aft than intended, so that the $C_{m\alpha}$ of the unaugmented aircraft may have become less stable than the data used in the design of the SCAS.

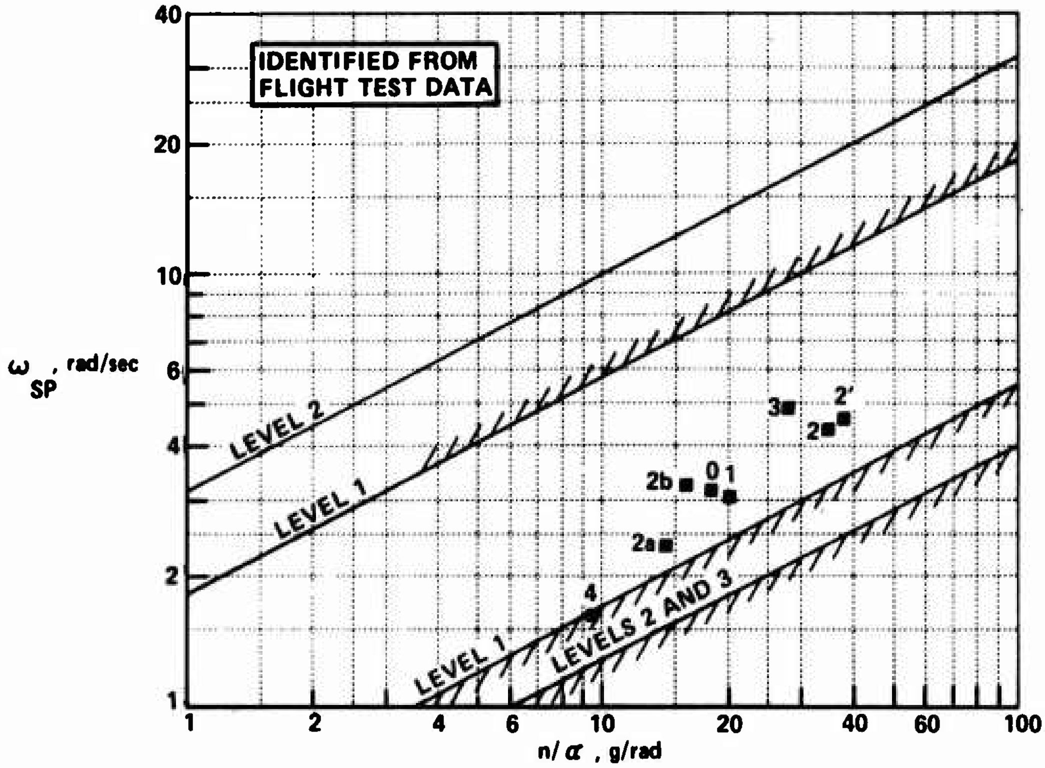


Figure 45 ω_{SP} vs n/α - - CONFIGURATION II-2 (α, q SYSTEM)

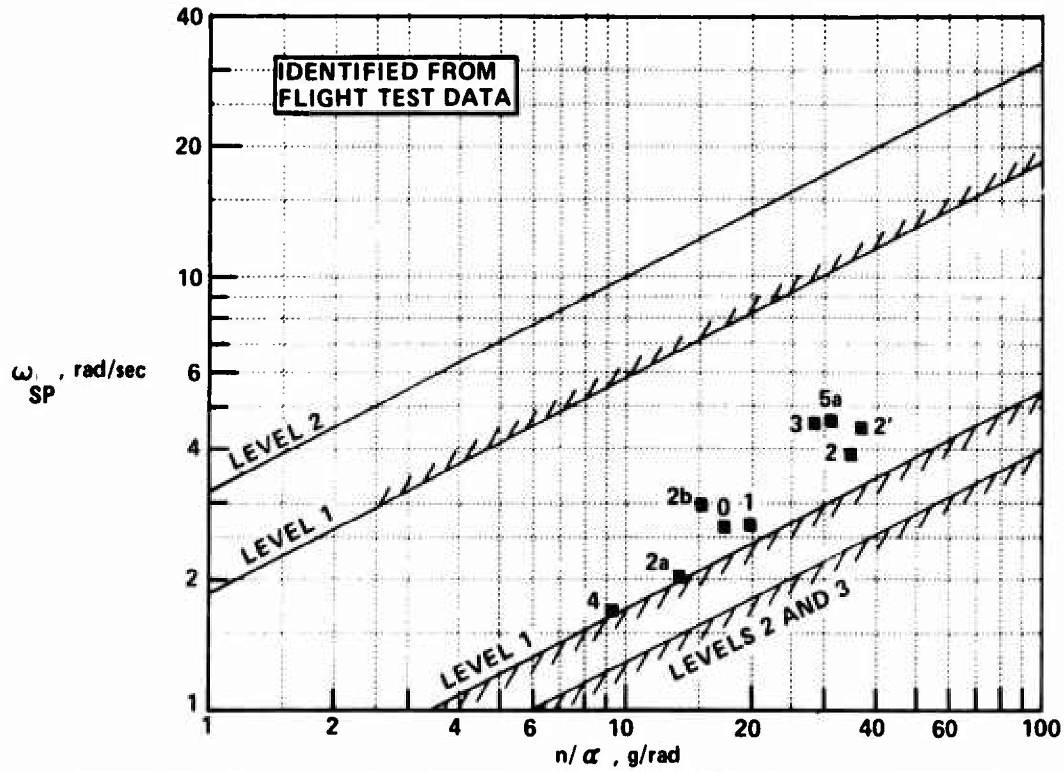


Figure 46 ω_{SP} vs n/α - - CONFIGURATION II-3 (α , q, n_z SYSTEM)

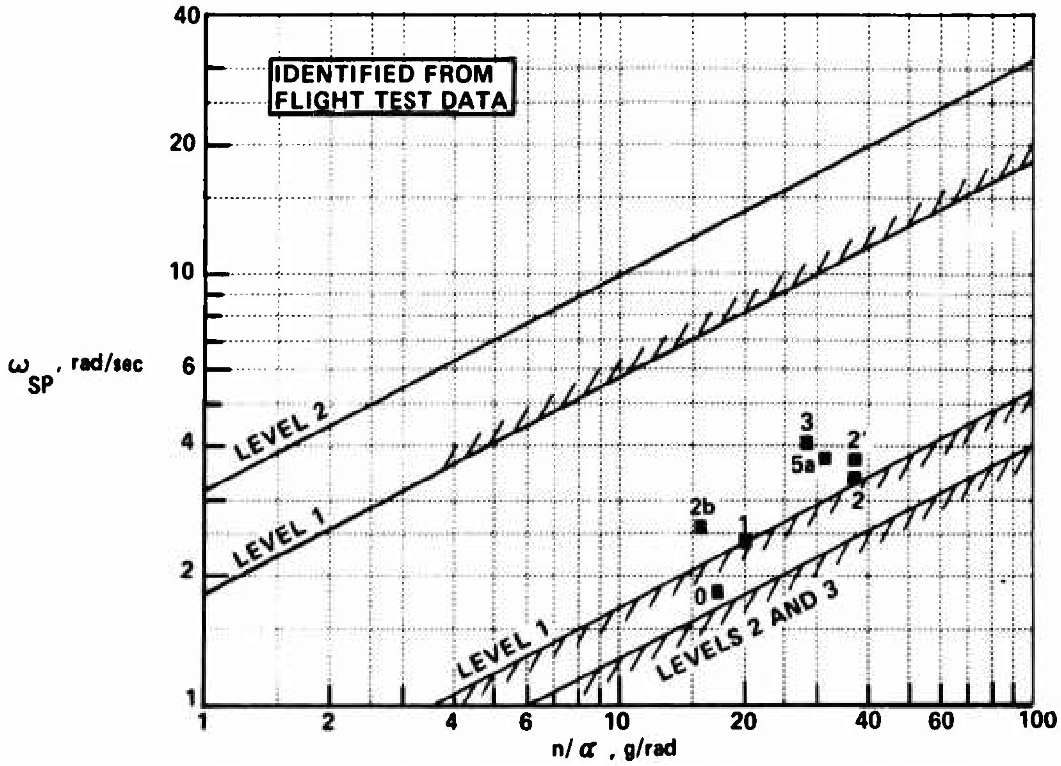


Figure 47 ω_{SP} vs n/α - - CONFIGURATION II-4 (q, n_z SYSTEM)

6.4 EVALUATIONS

The evaluations were conducted by having the evaluation pilot fly the profile of Figure 32 progressing from flight condition 1 through flight condition 6. As the evaluation pilot flew the NT-33A through the mission profile shown on the left side of Figure 32, the aircraft simulated, in a continuously varying manner, the longitudinal characteristics of a representative fighter airplane in the flight profile on the right side of Figure 32. For example, at flight condition 3, 25,000 ft and 270 KIAS, the NT-33A simulated the characteristics of the representative fighter at 45,000 ft and M = 1.8. Other flight conditions were likewise simulated. The NT-33A was programmed so that as it progressed from one flight condition to another on its mission profile, its characteristics, as augmented by the VSS, changed continuously with those of the simulated airplane progressing between the same flight conditions on the representative airplane mission profile.

6.4.1 Mission Definition and Evaluation Tasks

The general fighter mission comprises a variety of Flight Phases, including:

(1) The air-to-air intercept, tracking, and destruction of enemy aircraft.

(2) The delivery of air-to-ground weapons, or more simply, ground attack.

(3) Air combat maneuvering to gain the advantage against an opponent aircraft.

(4) Landing approach.

(5) The associated tasks such as formation flying, aerial refueling, and flight in instrument weather conditions.

It is generally not feasible to perform tasks of the variety and magnitude indicated above in one in-flight investigation, but in the current experiment it was desirable to perform maneuvers representative of the "basic" fighter missions. The following Flight Phases were chosen to be included in any given evaluation:

1. Ground Attack
2. Air Intercept Tracking
3. Air Combat Maneuvering
4. Landing Approach

With the exception of landing approach, in which the actual task was performed, the Flight Phases listed above had to be evaluated by performing a set of evaluation maneuvers representative of the maneuvering requirements of the fighter mission. Unfortunately, for the Phase II portion of this experiment, a second aircraft was not available to maneuver against or to track in order to perform the evaluations. The effects of this evaluation technique are noted in the Phase I portion of this report.

The procedure of using representative maneuvers has been frequently used in handling qualities experiments. When using this procedure, however, it is essential that the airplane mission requirements be clearly understood. The mission, the simulated airplane flight profile, the NT-33A profile, and the tasks to be performed as the profile progressed were discussed at length with each evaluation pilot, to ensure that each pilot understood the mission and that each pilot was evaluating the configurations for the same mission requirements. The intent of the experiment was to evaluate each configuration over an expanded portion of the representative fighter envelope by performing the above Flight Phases at the appropriate times in the flight profile previously defined.

Referring to Figure 32 for identification of the flight conditions, the evaluation maneuvers and the sequence in which they were performed was as follows:

(a) From Flight Condition 1 to Flight Condition 2, the evaluation pilot performed a ground attack dive bombing task, releasing his "bomb" at point 2. Upon bomb release, the effect of a forward c.g. shift equivalent to $\Delta c_{m_\alpha} = 0.01$ was simulated.

(b) The airplane was then climbed to the altitude for Flight Condition 3 and accelerated. The effect of the aerodynamic center shift was included as the simulated airplane entered supersonic flight. From Flight Condition 3 to Flight Condition 4, an air intercept pitch angle tracking task was performed. The tracking task was programmed on the pitch command bar of the NT-33A attitude director indicator. During the tracking task the airplane was decelerated to a low-speed, high angle-of-attack condition. The tracking task was identical to the discrete error tracking task used in Phase I of this experiment, which is described in paragraph 3.2.7.

(c) From Flight Condition 4, the airplane progressed to Flight Condition 5, again entering an area of supersonic flight for the evaluation pilot as the speed was reduced toward flight Condition 6. The maneuvers performed were those listed as items 3 through 5 on the pilot flight card presented in paragraph 3.1.3.2

(d) After the ACM, a let-down was made to the ILS course and an instrument low approach followed by a go-around was accomplished.

6.4.2 Evaluation Pilots

The two evaluation pilots who participated in this phase of the program were designated as Pilot R and Pilot L. A summary of their backgrounds is as follows:

Pilot R: A Calspan research pilot with 3500 hours total flying, of which 2500 hours was in jet fighters and trainers. He has previously served as evaluation pilot on several programs using variable stability airplanes. He is presently current as a fighter pilot with an Air National Guard unit.

Pilot L: A USAF test pilot with over 2500 hours of diversified flying time including 300 hours in fighter or fighter/trainer airplanes. He is a graduate of the USAF Experimental Test Pilot School, and most recent experience has been as Project Pilot on the Independent Landing Monitor Program.

6.4.3 Evaluation Procedure

Accomplishment of the mission profile, previously described, required approximately 50 minutes and constituted one evaluation. Two such evaluations were completed on a single NT-33A flight. The evaluation mission profile was performed six times by each evaluation pilot. The total flying time for this phase of the program was 20.4 hours. Fourteen flights were flown, seven of which were calibration and practice evaluation flights. Each pilot evaluated all five configurations and repeated his evaluation of one configuration.

To ensure that each evaluation mission profile was conducted in the same detail and that each of the flight conditions was met as scheduled, the pilot was provided with a flight card which detailed the entire profile for his in-flight guidance. A copy of the pilot's flight card is reproduced below:

EVALUATION TASKS AND PROCEDURES
NT-33A PROGRAM, PHASE II

1. After VSS engage at 5,000 ft MSL and 250 KIAS, climb to 12,000 ft at 250 KIAS. (F.C. 1)
2. Perform dive bomb run on ground target from 12,000 ft, 250 KIAS to 5,000 ft minimum and 330 KIAS maximum idle power, speed brake out. (F.C. 2)
3. At completion of dive bomb run, climb to 25,000 ft. Schedule climb to arrive at 25,000 ft at 210 KIAS. From 10,000 ft, 240 KIAS, reduce IAS 2 knots/1,000 ft of climb. (S.A. at 45,000 ft, M = 0.9).
4. Accelerate at 270 KIAS at 25,000 ft. (S.A. at 45,000 ft, M = 1.8, F. C. 3)
5. Reduce power to idle and perform discrete error tracking task level at 25,000 ft. (S.A. going from 45,000 ft, M = 1.8 to 35,000 ft, M = 0.7). Tracking task will terminate at T-33 IAS = 170 knots. (F.C. 4)
6. Descend from 25,000 ft, 170 KIAS to 12,000 ft, 370 KIAS (S.A. 15,000 ft, M = 1.2, F.C. 5).
7. Perform ACM type maneuvering at 12,000 ft until T-33 speed is reduced ao 250 KIAS. (S.A. 15,000 ft, M = 0.6).
8. Descent to 2,000 ft MSL at 250 KIAS. At 2,000 ft, slow to 140 KIAS and perform ILS low approach, NT-33A configured with landing gear down, flaps full down, and speed brake out. (F.C. 6).

As each of the four tasks was completed at the appropriate point in the evaluation mission profile, the pilot recorded his comments and pilot rating for that particular task while enroute to the flight condition for the next task. This procedure was followed until the entire profile was completed, at which time the pilot recorded general comments and an overall rating for the configuration. The entire process was then repeated for the second evaluation of the flight.

6.4.4 Pilot Comment and Rating Data

Pilot comments and ratings were the primary data obtained in this phase of the program. Good pilot comments are, of course, crucial for the proper interpretation of the pilot rating data. In this experiment, a departure was made from the customary practice of obtaining one overall pilot rating for the evaluation. This was necessary because of the four Flight Phases included in the overall mission. Therefore, the evaluation pilots were requested to comment on and rate each of the fighter Flight Phases previously listed and then make general comments and assign an overall rating for the complete mission task. As a result, five pilot ratings were assigned for each evaluation. An interesting result of this procedure was that the overall pilot rating was usually better than the poorest rating obtained on one or more of the subtasks evaluated.

The pilot ratings were assigned in accordance with the Cooper-Harper rating scale previously discussed in paragraph 3.1.4. The pilots were encouraged to record comments at any time during the evaluation, but to aid the acquisition of a consistent set of comment data, the pilots were requested to comment on the items listed on the following Pilot Comment Card:

PILOT COMMENT CARD (PHASE II)

Specific Comments

A. Comments applicable to all tasks/flight phases

1. Ability to trim?
2. Are stick forces satisfactory?
3. Does stick force required for maneuvering change with airspeed? Is the change acceptable?
4. Is stick motion satisfactory? If not, why?

B. Specific comments for each Flight Phase

1. Ground attack
   a. Pitch attitude control and ground target tracking. Discuss any difficulties.
   b. Discuss any pitch attitude transients encountered during bomb release and ability to control the transients.
   c. Normal acceleration control during target acquisition and tracking.
   d. Assign pilot rating for ground attack task.
2. Air Intercept
   a. Discuss pitch attitude transients encountered in the transonic range and ability to control the transients.
   b. Pitch attitude control and tracking capability.
   c. Pitch attitude control at low-speed, high-altitude conditions. Discuss any longitudinal control or trim difficulties.
   d. Are there significant trim changes with speed changes?
   e. Assign pilot rating for air intercept task.

3. ACM
   a. Normal acceleration control during ACM.
   b. Tracking capability during ACM .
   c. Longitudinal control in turns.
   d. Predictability of aircraft response in ACM type maneuvering (initial and final response).
   e. Assign pilot rating for ACM.
4. Landing Approach
   a. Pitch attitude control.
   b. Speed control.
   c. Flight path control.
   d. Any problems with execution of missed approach?
   e. Assign pilot rating for the landing approach.

Summary Comments

1. Good features.
2. Objectionable features.
3. Special piloting techniques.
4. Pilot rating for overall mission.
5. Primary reason for the pilot rating.

The pilot comment card is quite lengthy, but this was necessary because of the number of tasks to be accomplished in a fifty-minute evaluation. The evaluation pilots were instructed that the specific comments and rating for each Flight Phase in the evaluation should be recorded immediately after the performance of the Flight Phase. The specific comments that applied to all Flight Phases, A1 through A4, could, however, be recorded at the completion of the entire evaluation; and they usually were. At times, as can be seen from the pilot comments in Appendix II, some of the comments listed under "A" above were omitted, as were some of the "Summary Comments"; or the comments for these items were integrated with the specific comments for each Flight Phase.

The "Cooper-Harper" rating was the only rating recorded in this phase of the experiment. No attempt was made to record a separate PIO tendency rating and, since random disturbance inputs were not used, there was no turbulence effect rating assigned.

6.4.5 Supporting Data Acquisition

Both an oscillograph recorder and a digital tape recorder were used to document the airplane response to both a manual and automatic elevator doublet, and elevator step. Airplane state, pilot control usage and tracking task error were recorded during the air intercept tracking task. Pilot comments and ratings were recorded in flight on a voice tape recorder installed in the NT-33A. These recordings were later transcribed for publication and analysis. As a backup, the safety pilot manually recorded the pilot ratings on the flight card that provided the variable stablity and flight control augmentation gain settings for each configuration.

6.5 EQUIPMENT

Evaluations were performed in the USAF NT-33A three-axis, variable stability airplane, shown in Figure 10 and described in paragraph 3.2. The details of the VSS modifications and description of equipment peculiar to this phase of the experiment have been discussed in paragraph 6.2. The gun sight used in the Phase I experiment, paragraph 3.2.1, remained in the airplane for the ground attack task of the Phase II experiment.

6.5.1 Feel System Characteristics

The feel system's frequency and damping ratio and its force gradients were not changed from those used in Phase I. These characteristics are described in paragraph 3.2.3.

It should be noted, however, that a breakout force was included in the elevator control channel; but this was incorporated in the flight control system design. Figure 31 indicates the arrangement that was used. Force commands were used from the elevator stick, with the command passing through the network and providing the breakout before being input to the NT-33A elevator feel system. In this way the pilot properly felt the breakout force without stick motion, but once the breakout force level ($\pm$ 1.5 lb) was exceeded, then the feel system responded and the appropriate amount of stick motion accompanied the stick force input.

The elevator stick force per unit normal acceleration, F_s/n, value was determined during the FCS design and is discussed in Section 6.3.

6.5.2 Lateral-Directional Characteristics

The lateral-directional VSS feedback gains used in this phase of the program were the same as the gains used in the Phase I portion. A "good" set of lateral-directional characteristics that would not affect the longitudinal evaluations was produced. Paragraph 3.2.5 documents the lateral-directional characteristics for the two flight conditions of Phase I. The gains selected were maintained at a constant value over the entire evaluation mission profile; therefore, the lateral-directional characteristics varied as a function of both flight conditions and changes in moment of inertia as the fuel was consumed. Since two evaluations were conducted per flight, the lateral-directional characteristics on the second evaluation were different from those on the first because of the decreased fuel state of the NT-33A airplane.

Section VII
RESULTS OF PHASE II IN-FLIGHT EVALUATIONS

7.1 PILOT RATING RESULTS

The pilot rating results for the complete Phase II evaluation program are shown in Table XVI. This table shows that the unaugmented simulated airplane, Configuration II-1, had major deficiencies, receiving overall pilot ratings of PR = 7.5 and PR = 9. Further, the unaugmented airplane was not satisfactory for any of the fighter tasks evaluated. The best pilot rating obtained was PR = 5 in the ground attack task by Pilot R, but Pilot L's rating in the same task was PR = 7.

All four of the flight control augmentation system configurations, II-2 through II-5, received an overall satisfactory pilot rating by both evaluation pilots. The poorest pilot rating obtained for any of the tasks evaluated was PR = 4. Appendix III contains the pilot comments for each configuration.

Identification of the characteristics of each configuration, the identification procedure used, and a comparison of resulting short-period characteristics and stability derivatives compared to predicted values are contained in Sections 6.2 and 6.3. Samples of identification records and time histories are shown in Appendix II.

The following paragraphs discuss briefly the pilot's assessment of each of the configurations evaluated and describe his difficulties in the performance of each task.

7.1.1 The Unaugmented Simulated Airplane

In the ground attack task, the unaugmented airplane was very steady in pitch attitude once the pipper was on target, but attempts to make tracking corrections were difficult because of pitch attitude overshoots or the lack of

Table XVI

PILOT RATINGS FROM PHASE II

CONFIGURATION	UNAUGMENTED SIMULATED AIRCRAFT II-1		α, q II-2		α, n_z, q II-3		n_z, q II-4		n_z, q P+I** II-5	
TASK / PILOT	R	L	R	L	R	L	R	L	R	L
GROUND ATTACK	5	7	3 / 2*	3 / 2	2	1	3	2	4	3
AIR INTERCEPT TRACKING	7.5	7	2.5 / 2.5	4 / 1	2.5	1	2.5	1	2	3
AIR COMBAT MANEUVERING	7	6	4 / 2.5	2 / 1	2.5	1	4	1	2	3
LANDING APPROACH	8	9	2.5 / 2	2 / 2	2	2	3	1	1	2
OVERALL RATING	7.5	9	3 / 2	2 / 1	2	1	3	1	2	2

*PILOT RATINGS UNDER DIAGONAL LINE ARE FOR A REPEAT EVALUATION.

**INDICATES PROPORTIONAL PLUS INTEGRAL CONTROL IN THE FORWARD LOOP.

predictability of the final response. Also, to acquire and maintain a desired g was quite difficult. The pilot would experience a stick force reversal; he would have to push the stick forward to acquire and maintain a positive g after the normal acceleration response developed. After bomb release, this problem was alleviated because of the forward shift of the center of gravity.

In the air intercept task, stick forces were large, $F_s/n \approx 65$ lb/g at Flight Condition 3, and contending with small trim change requirements was difficult. Attempts at tracking resulted in a continuous pitch attitude oscillation. At high altitude and low speed, the pilot considered the airplane dangerous. Any diversion of his attention from controlling the pitch attitude resulted in divergent pitch departures or in the pilot's words, "the airplane would wrap up."

In ACM, the pilot noted the differing characteristics of the airplane with changes in speed. The pilot, relating his comments to NT-33A indicated speed rather than simulated airplane (S.A.) speed, stated that at 370 KIAS (equivalent to M = 1.2 for the S.A.) he could accurately acquire and maintain a desired g but at 250 KIAS, (equivalent to M = 0.6 for the S.A.), there was a tendency to "dig in" and a lack of precision in normal acceleration control. Stick forces were too large throughout the ACM, $F_s/n \approx 56$ lb/g at Flight Condition 5, but lightened considerably at lower speeds and as the airplane normal acceleration response developed. Any attempts at tracking resulted in a pitch attitude oscillation.

In the landing approach, the pitch attitude control was considered dangerous. The pilot stated that the airplane appeared to be statically unstable longitudinally, the stick forces were high, and he could never find a trim point. The airplane slowly pitched up or down and the forces necessary to counteract the pitch divergence were uncomfortably large. Speed control was of course difficult because of the difficulties with pitch attitude control.

In all the tasks evaluated, the pilot encountered considerable difficulty, but in his summary comments he noted that the landing approach was the worst phase.

7.1.2 The Augmented Simulated Airplane

As mentioned previously, the airplane as augmented by each of the four control augmentation systems was found to be satisfactory overall for all four systems. There were minor deficiencies as discussed in the following paragraphs, in some of the fighter tasks evaluated, and the deficiencies varied with the flight control augmentation system. The poorest pilot rating obtained was PR = 4, which occurred only four times in a total of 50 pilot ratings assigned during the evaluations of the augmented airplane configurations.

Configuration II-2, the α, g system, was assigned PR = 4 by Pilot R in the ACM task on the first evaluation of the configuration. On his repeat evaluation, Pilot R assigned a PR = 2.5 in the ACM task. His main objection in the PR = 4 case was the heavy stick forces, F_s/n = 10 lb/g, and an occasional feeling of a slight feedback or pulsing on the control stick. For the PR = 2.5, the slight stick pulsing was still noted, but there was no mention of high stick forces. Pilot L assigned a PR = 4 in an intercept tracking with Configuration II-2, but on the repeat evaluation he assigned a PR = 1. The PR = 4 resulted from pitch attitude overshoots during the tracking task on Pilot L's first evaluation flight in the program. There was no mention of overshoots on the repeat evaluation later in the program.

Configuration II-4 was rated PR = 4 in the ACM task by Pilot R. He found the normal acceleration control and pitch attitude quite good at high speed, but as the speed was reduced during the performance of the ACM task, the precision of normal acceleration control deteriorated and the pitch attitude control was degraded. Pilot L assigned a PR = 1 for this task and listed no deficiencies in his comments.

Configuration II-5, the n_z, q system with proportional plus integral control in the forward loop and a 4 rad/sec prefilter, was assigned a PR = 4 in the ground attack task by Pilot R. The initial pitch attitude response was slow, which caused a tendency to overshoot the target when making a tracking correction. Pilot R stated that he could hold the pipper on target quite precisely. Pilot L assigned a PR = 3, but he also mentioned a tendency to overshoot the target a bit.

From the above comments, each of the configurations (II-2 through II-5) had some deficiencies in some of the tasks evaluated. All the configurations were not therefore equally good for every task. When the rating of both pilots are considered, however, none of the configurations was rated as less than satisfactory by both pilots in any Flight Phase. From the pilot rating and comment results obtained, there is no basis for selecting any single configuration as the best. It is possible to select the poorest configuration for a given fighter Flight Phase in some cases. For example, Configuration II-5 appears to be slightly less desirable for ground attack than do the other configurations, but any differences of this nature are certainly marginal.

Section VIII
CONCLUSIONS FROM PHASE II EXPERIMENT

The criteria for the pitch response characteristics used in the design of the flight control systems evaluated in this program were developed from work reported in Reference 1 and from the requirements of MIL-F-8785B. All four of the flight control augmentation systems were given satisfactory pilot ratings (PR $\leq$ 3) by both evaluation pilots. This result confirms that the design criteria, if met, will ensure good flying qualities for fighter airplanes. Since all tasks evaluated were generally satisfactory, the criteria are not limited to the precision tracking task; but if properly applied, they will provide satisfactory flying qualities for other fighter airplane Flight Phases.

The results of this program also demonstrated the following:

1. For fighter aircraft in typical fighter Flight Phases, it is not necessary in SCAS design to increase the order of the overall system. In this investigation, three of the four systems were designed using constant speed, basic airframe dynamics. In each case good augmented aircraft configurations were obtained without increasing the order of the transfer functions. All three of these systems, using n_z, q ; α, q or α, n_z, q feedbacks with appropriate, but simple gain scheduling provided satisfactory flying qualities for all Flight Phases evaluated. The four Flight Phases spanned a quite large range of unaugmented simulated aircraft dynamics.

2. The use of angle of attack as a SCAS feedback signal has been demonstrated in flight to be desirable. Both the α, q system with no n_z feedback and the α, n_z, q system with the appropriate blending of the α and n_z signal provided satisfactory flying qualities in all the Flight Phases evaluated. Most modern fighter airplanes have an installed angle of attack sensor to provide a cockpit display of angle of attack. In

addition, the angle of attack has been found to be an important feedback signal for departure prevention for some of this class of aircraft (see, for instance, Ref. 15). Therefore, it is desirable to use α as a feedback signal in the design of SCAS for this class of aircraft.

3. It has been demonstrated in the current program that a variety of longitudinal SCAS configurations can be designed to meet the Level 1 flying qualities requirement. It is conceivable, therefore, that a logic could be built to switch from one system configuration (e.g., the α, q, n_z system) to other systems (such as the α, q system or the q, n_z system) whenever a failure is detected in n_z or α sensors.

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Appendix I

PILOT COMMENTS FROM PHASE I EXPERIMENT

This appendix contains pilot comments for each configuration evaluated in the Phase I experiment. The comments are arranged with the group of n/α = 18.5 g/rad cases followed by n/α = 50 g/rad cases. Within the two n/α groups the comment sets are in numerical order by basic short-period configuration and in alphabetical order within each set of basic configurations; for example, Configurations 1B, 1D, 1E, etc. followed by Configurations 2A, 2C, 2D, etc. Within each configuration, the comments are arranged in order: evaluations with a target airplane first, evaluations without a target airplane second, and evaluations in the aerial refueling task third. For configurations evaluated by both pilots, Pilot B's comments immediately follow those of Pilot A within each subset for target or no target. Identification of the short-period and flight control system characteristics can be obtained by reference to Figure 5.

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CONFIGURATION 1B WITH TGT PILOT A PR 4 PIOR 2 TR C
EVALUATION FLT 2

STICK FORCES

Stick forces and motion were quite satisfactory. The motion wasn't noticeable.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response was a little bit weird. There was a tendency to overcontrol the airplane in g, but I found I could track pretty well.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Tracking capability was good. There was a slight tendency to bobble the airplane.

NORMAL ACCELERATION CONTROL

There was a tendency when trying larger maneuvers, higher g, to get more acceleration than I really wanted

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence did move the nose around. It made life more difficult and pointed out the tendency to bobble the airplane a little bit. It showed up a lot in the lateral-directional, and I found myself wiggling the rudders to keep the airplane on the target. Lateral-directional control, however, was satisfactory.

GOOD FEATURES

I would list tracking capability as a good feature.

OBJECTIONABLE FEATURES

The tendency to overcontrol in g for gross maneuvers.

PRIMARY REASON FOR PILOT RATING

I found the over g tendency fell only in the minor but annoying deficiency category and felt that some pilot compensation was required but it was certainly not much more than moderate. There was a slight tendency to bobble the airplane which I didn't particularly like. Turbulence caused a minor deterioration of my task performance.

CONFIGURATION 1B WITH TGT PILOT B PR 5 PIOR 3 TR None Given
EVALUATION FLT 13

ABILITY TO TRIM

No problem.

STICK FORCES

Stick forces were a li' e bit higher than enjoyable. It meant that I just had to stick my arm down harder on my leg to take care of the stick forces. It could be that I was just squeezing the stick too hard.

PREDICTABILITY OF RESPONSE

When I held back on the stick, I was not really sure what g load I was going to get. The longitudinal and lateral of the airplane did not appear to be hooked to the stick. Extrapolating this to a 7 g load, I'm not sure that you would not overstress the airplane. As I came into the stick to make an acquisition type maneuver while watching the target, the g load might go over what I was shooting for because I didn't seem to have a feeling between the stick and the seat of the pants on the g load build up.

CONFIGURATION 1B (Cont.)
EVALUATION FLT 13

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

There didn't seem to be any trouble tracking with it but a couple of times I noticed some pitch bobbling of plus or minus 5 pippers. I didn't know if I was doing that or the airplane was doing that but I did see it. It was bobbling right up and down the axis of the target airplane, so I didn't feel too bad about that. But it might have turned out to be objectionable if I had looked at the airplane a little bit more.

NORMAL ACCELERATION CONTROL

You are not looking at the g meter, you haul back on the stick and you don't know where the g load is going to end up. Once you get to g load, it doesn't seem to be too much trouble to hold pretty close to your g load except you do bobble the pipper on the target.

EFFECTS OF RANDOM DISTURBANCE INPUTS

I don't know if we turned on the turbulence in this evaluation; if we did, it certainly was nothing that was outstanding because I don't remember turning it on or not turning it on.

GOOD FEATURES

Not a bad tracking airplane. It's an airplane that does acquire the target up to 3 g's, 3-1/2 g's.

OBJECTIONABLE FEATURES

Whether or not you would come back with bent airplanes in a dog fight up around 7 g's is hard to tell because of the lack of predictability on where the g load is going to end up when you haul back on the stick. From the flying we did and the g load we used, it was not objectionable. Extrapolating at the higher g may turn out to be objectionable.

PRIMARY REASON FOR PILOT RATING

It had adequate performance during acquisition, but it would require considerable pilot compensation to keep from over g'ing. If you were to take it up to a higher g load, you might not be able to acquire the target at the rate you wish if you were careful not to overstress the airplane. In the tracking phase it requires very little pilot compensation to keep the tracking phase going good. I did no turbulence effect rating because I really didn't know anything about that.

CONFIGURATION 1B WITHOUT TGT PILOT A PR 7 PIOR 1 TR C
EVALUATION FLT 8

ABILITY TO TRIM

Ability to trim that configuration was quite poor. I could put the airplane on an attitude and it would hold it for quite a while and then it would slowly go back to the trim position. So getting it all trimmed up wasn't as easy as it should have been.

STICK FORCES

Stick forces were okay. Let me qualify that a little bit. When I maneuvered, the airplane really wanted to take off; I found myself having to check forward to try and stop this tendency to get more g than I wanted. The forces and displacements both, in being able to do that, were okay. I wouldn't want to change the forces. I liked the maneuvering forces; I just didn't like the feeling of having to push to stop the airplane from over rotating.

PREDICTABILITY OF RESPONSE

Initially the airplane response was a little slow coming on, but not bad. I could start and stop the response at will.

CONFIGURATION 1B
EVALUATION FLT 8 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I thought tracking capability was very good. I could just pull the nose up and if I just made small corrections, I could stop it almost any place I wanted to without a significant overshoot. There was a tendency when I flew the tracking task to overcontrol a little bit. I was trying to do the task quite aggressively, but I could get the airplane back where I wanted and have the needle stop right in the center. Tracking capability was good.

NORMAL ACCELERATION CONTROL

The big problem was normal acceleration control. When I tried to maneuver the airplane rapidly, there was a strong tendency to overcontrol. The airplane would start rotating and then it would just want to keep on going. If I did things aggressively and abruptly I overcontrolled quite dramatically, so I didn't like it at all. I think you would have a real tendency to break the airplane if you got into a real dog-fight with somebody and it was your airplane against his.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random noise had some effect, but I really didn't think it was significant. It moved the airplane around more than perhaps I would like to have for a fighter, but it was still okay.

INSTRUMENT FLIGHT PROBLEMS

No problems IFR that I hadn't seen VFR. The two tracking tasks were quite easy to do.

GOOD FEATURES

I have to say that the tracking capability was pretty good for small corrections.

OBJECTIONABLE FEATURES

Stick forces were quite satisfactory for tracking, but less satisfactory for maneuvering because there is a real tendency to over g the airplane and that is the major objection. I think the thing that keeps this airplane from being acceptable is the strong tendency to over g.

PRIMARY REASON FOR PILOT RATING

I did not think that the airplane was acceptable. You cannot obtain adequate performance, and I think you would break the airplane. I don't think you could do the job because high g maneuvering must be avoided. I don't think controllability is a problem. All you really have to do is slack off and push forward. You can stop the airplane; it's not going to get away from you. There was no tendency toward PIO when doing the tight tracking. You get an undesirable motion when you attempt to maneuver the airplane through a high g value and you can stop that. In turbulence there was no more than a minor deterioration in my performance.

CONFIGURATION 1B WITHOUT TGT PILOT B PR 6 PIOR 4 TR B
EVALUATION FLT 11

ABILITY TO TRIM

Trim was no problem.

STICK FORCES

Stick force proved to be too light. It coupled in with some of the other things, but I didn't change the gearing Looking at the stick and making attitude changes longitudinally, it appeared that the stick moved very, very little. It was almost like a force stick, and I got quite a bit of g with little, if any, stick motion.

CONFIGURATION 1B
EVALUATION FLT 11 (Cont.)

PREDICTABILITY OF RESPONSE

It was very hard to predict the response I was going to get to a pilot input. T describe it: If I started to pull, looking for the nose to move, and I pulled, pulled, and pulled; then all of a sudden there went the nose, and I would have to try stopping the nose motion with a force gradient that I would normally use under normal piloting techniques, and this tended to give me an overshoot, a little oscillation.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Once I had established attitude, it was easy to hold that attitude and if the target didn't move I was sure I wouldn't have any trouble tracking it. But if I had to make a large excursion from whatever attitude I was holding to get a new attitude, it was hard to do, I couldn't get there as rapidly or precisely as I would have liked.

NORMAL ACCELERATION CONTROL

It seemed as if I didn't have control of the normal acceleration until I got near the desired g. Then I could hold the g, but it was hard to get there as quickly as I would have liked. That affected the longitudinal control in steep turns.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random noise was just like any bothersome turbulence; it didn't seem to grossly affect things in any way.

INSTRUMENT FLIGHT PROBLEMS

IFR problems, with the way the airplane was behaving, if you were hand flying and since most fighters don't have a g meter where it can be seen very well, you would tend to overstress the airplane if you had to make an IFR fly up, pitch up maneuver.

GOOD FEATURES

Once I got on the g load, or on the tracking task, it was very easy to hold what I had.

OBJECTIONABLE FEATURES

It was very unpredictable how I was going to get to a new attitude that I wanted. I think that if I had tried to extrapolate that to 7 g instead of 3-1/2, I might have overstressed the airplane. It took special piloting techniques because I had to say to myself, "I don't want to overstress the airplane but I have to make a gross maneuver and so I have to counter my inputs. After I load the airplane a little bit, I've got to stop the response and I can't pussy-foot, so I must make a large control input to make it stop, and that causes it to oscillate around the stopping point." Also, because of the relationship between the light stick forces, and the small stick motions, close pilot attention must be paid to the g load. In a pull up or dive bomb run when you just pull the stick back or put a certain amount of force on the stick to start the maneuver because you want to see the nose start to move, that may be too much above 7 g's. It may be the same thing in an acquisition task where you see the target, to acquire you have to make a gross maneuver right now. Because of the forces and motion that you have to put on to the stick to get that gross maneuver started, you may end up overstressing the airplane.

PRIMARY REASON FOR PILOT RATING

I would rate it as having very objectionable but tolerable tendencies. I think I could do a tracking task with it, but I think it would require extensive pilot compensation so that I wouldn't overstress or so that I could keep the airplane tracking the way I wanted it to. In turbulence, I would say no effort was required, no significant deterioration. Pilot-induced oscillations tended to develop when an abrupt maneuver was initiated, like an acquisition maneuver. You have to reduce your gain if you are extrapolating out to 7 g's because if you don't you would probably overstress the airplane.

CONFIGURATION 1B REFUELING PILOT A PR 1 PIOR 1
EVALUATION FLT 16

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces were satisfactory and I didn't see any reason to change the stick motion.

PREDICTABILITY OF RESPONSE

Airplane response to pilot inputs was really good. I could look right at the basket, and not have to fly on the tanker as a reference, and plug right in. I got so that I could pick out the center of the basket and fly the probe into that. It was really excellent.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during in-flight refueling was just the best I have ever seen. Tracking capability was good.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker couldn't have been any better than what we had there. The longitudinal control during the in-flight refueling was just really excellent.

GOOD FEATURES

The ability to control that airplane in the in-flight refueling task was really excellent.

OBJECTIONABLE FEATURES

None that I could see.

PRIMARY REASON FOR PILOT RATING

It was really excellent. The primary reason was that the precision with which I could fly that airplane was just outstanding.

CONFIGURATION 1D WITH TGT PILOT A PR 3 PIOR 1 TR B
EVALUATION FLT 7

ABILITY TO TRIM

Ability to trim was really pretty good.

STICK FORCES

Stick forces were quite satisfactory. Stick motion was satisfactory. In general, I thought the feel of the airplane was pretty good.

PREDICTABILITY OF RESPONSE

There was a little tendency to have the airplane dig in, but not bad, and certainly not something that required a check on the controls.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability during ACM were very good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was only good.

CONFIGURATION 1D
EVALUATION FLT 7 (Cont.)

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence moved the airplane around but didn't seem to have any major effect.

GOOD FEATURES

Tracking capability was good.

OBJECTIONABLE FEATURES

There was a slight tendency to overcontrol in g, but not very bad. I thought that the airplane was satisfactory, and minimal compensation was required. Turbulence had only a minor effect. More effort was required, but no real significant deterioration.

CONFIGURATION 1D WITH TGT PILOT B PR 3 PIOR 1 TR C
EVALUATION FLT 14

ABILITY TO TRIM

Ability to trim, no problem.

STICK FORCES

Stick forces were a bit high, but during the acquisition phases I could trim out.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response in the acquisition phase was a little difficult. I pulled on the stick and the nose rise didn't give me an indication where the g was going to end up. It looked like it might go to a higher g than expected. But, I didn't have to make any abrupt stopping of the g load.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was very good. It was easy to keep the pipper on the target. Tracking capability was good.

NORMAL ACCELERATION CONTROL

Normal acceleration control could have been better, but it was sure to get the airplane where I wanted to go.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence did not affect the acquisition at all; that was noticeable. It certainly affected the tracking. A gust upset in the turbulence would disturb the pipper longitudinally and I would have to fight with it. It was much more difficult with random disturbances.

GOOD FEATURES

The airplane was quite a good tracker. I could hold the pipper on the target with very little pilot workload. Stick forces were high during the acquisition stage, but it seemed like I could pull it up and right into buffet, hold it on buffet, and not notice any bobbling tendencies during the acquisition phase. The g load came on a little bit faster than the nose seemed to indicate as the nose was rising, but didn't take any special techniques. It didn't seem to want to overstress itself. I think it was a good airplane. That's what I would have to say.

OBJECTIONABLE FEATURES

I would say none, except I couldn't track too well with gust disturbances.

PRIMARY REASON FOR PILOT RATING

Is it satisfactory without improvement? Yes. Minimum pilot compensation required for desired performance, I could handle the acquisition phase very easily and the tracking task looked very good without turbulence. It took quite a bit of compensation with turbulence. There was no tendency for the pilot to induce undesirable motions.

CONFIGURATION 1D   WITHOUT TGT   PILOT A   PR 7   PIOR 3   TR B
EVALUATION FLT 27

ABILITY TO TRIM

Ability to trim was only fair. I could get it trimmed, but it didn't hold its trim very well.

STICK FORCES

Stick forces were okay. It was a little bit heavy initially and then the airplane had a tendency to dig in, so that the forces tended to lighten up as I attempted gross maneuvers, and it was quite easy to overcontrol the airplane in g. Stick motions were okay. The thing I did notice was that there was a slight hesitation when I put an input into the stick before the airplane responded. Consequently, I was aware of the stick motion rather than having the airplane move right along with the stick motion. But I still say it was okay.

PREDICTABILITY OF RESPONSE

Initially the airplane was a little slow coming on, not bad; it was reasonably maneuverable. The big problem I had was that I tended to overcontrol the airplane in g anytime I did gross maneuvering, and I really had to discipline myself to keep from over g'ing the airplane; so final response was not very predictable.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability were fair to good. The airplane was well damped; I could stop the nose pretty much where I wanted to although I couldn't move it quite as rapidly as I would have liked. The tracking capability was fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was the thing that really was a detriment, particularly when attempting to do fairly rapid and gross maneuvers. I almost always ended up digging in. The same problem occurred in steep turns. Initially getting the turn established was the big problem. Once I was in a turn and steady, then holding the turn was no problem.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbance didn't seem to have a major effect on the airplane; matter of fact, very little. There was no more than a minor deterioration of my performance.

INSTRUMENT FLIGHT PROBLEMS

On the IFR portion, heads down, tracking task I found that I had about 2 or 3 overshoots before I got the airplane settled down with the needle in the center, particularly when I tried to do things rapidly. So there was a slight tendency to overcontrol the pitch attitude during the tracking task when trying to do it quite abruptly, but these are some of the problems I had seen VFR, although I would say that I thought my VFR tracking capability was better than what I saw on the tracking needles.

GOOD FEATURES

I thought the tracking capability was fair and maybe fair leaning toward good.

OBJECTIONABLE FEATURES

The big major objection was the strong tendency to overcontrol the airplane in normal acceleration when maneuvering abruptly. I am really having a hard time in my mind deciding how bad I feel that was, because with a little bit of discipline I found that I could keep from over g'ing it. I had to put in fairly large inputs initially and then back off on them as I started getting g on the airplane in order to keep from overcontrolling it.

PRIMARY REASON FOR PILOT RATING

I'm not going to buy it because of the over g'ing tendency.

CONFIGURATION 1D WITHOUT TGT PILOT B PR 4 PIOR 2 TR B
EVALUATION FLT 12

ABILITY TO TRIM

No problem trimming.

STICK FORCES

Stick forces appeared to be light, but no problem in the gearing.

PREDICTABILITY OF RESPONSE

The nose seemed to follow the stick when I started the tracking maneuver, either acquiring or tracking. Then I had to stop the g load and the change in pitch rate because it felt like the airplane was quite neutral. At 3-1/2 g's I could lift my hands off the controls and it would just settle on 3-1/2 g's. If I didn't make an effort to stop at the proper g, it was not predictable.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I would fairly well put it where I wanted and leave it, and I could track with it.

NORMAL ACCELERATION CONTROL

Normal acceleration control was difficult until I learned how to stop at the g load that I wanted. I could put in a stick force, the nose would start moving and it would appear that I would get the g I wanted, except if I kept going at that stick displacement or force, the g would keep right on building. I actually had to force the nose to stop at the desired g load.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Effects of random disturbances, no problem; I just had to pay a little more attention to the airplane.

INSTRUMENT FLIGHT PROBLEMS

None.

GOOD FEATURES

The stick forces were light and comfortable. It felt as if I could track with this airplane

OBJECTIONABLE FEATURES

The fact that the stick forces were not related to the g load. I would put a stick force in there; it would just go and establish the g, and the forces would lighten as the g would increase and finally the forces would be down near zero, not to zero, but the g load would stabilize. I had to pay attention to stop the g load where I wanted, and therefore stop the attitude of the airplane for tracking.

PRIMARY REASON FOR PILOT RATING

It had minor but annoying deficiencies. The required pilot compensation was to get used to the fact that g load did not increase with stick force toward the g load I was shooting for. Increased pilot effort with turbulence; there was more effort required but I would say no sigificant deterioration. Pilot-induced motions could be prevented or eliminated by pilot techniques by making sure that I stopped the g load.

CONFIGURATION 1D REFUELING PILOT A PR 4.5 PIOR 2
EVALUATION FLT 17

ABILITY TO TRIM

Ability to trim was fair.

STICK FORCES

Stick forces and motion were satisfactory.

PREDICTABILITY OF RESPONSE

The initial response seemed to be slow, final response a little bit uncertain.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control for refueling was only fair. It was almost inevitable that I got a slight pitch oscillation just before going into the basket no matter how hard I worked at it. I didn't seem to be able to stop it. My ability to track the refueling drogue was only fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was okay.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was okay. The kinds of motions I was talking about were small. I did insert the probe a couple of times in the turns. I still got that slight, one- or two-cycle oscillation before getting into the basket.

GOOD FEATURES

I could certainly do the task; it was acceptable. It wasn't a particularly good airplane.

OBJECTIONABLE FEATURES

I could fly well near the basket, but I never had that last fine precise control I thought I would like to have, and that was the major objection. A tendency to set up maybe a one-cycle oscillation before getting the probe into the basket was objectionable. I really had to caution myself to make nice small inputs, and I'd chase the basket motions because I was always behind the airplane.

PRIMARY REASON FOR PILOT RATING

I didn't think the plane was satisfactory; it is more than a minor, but it's not in the category of being moderately objectionable. I did get an undesirable motion which I wasn't able to completely eliminate, but I could control up close and get it into the basket without numerous attempts.

CONFIGURATION 1D REFUELING PILOT A PR 4 PIOR 1.5
EVALUATION FLT 18

ABILITY TO TRIM

Ability to trim was fair.

STICK FORCES

Stick forces were satisfactory. Stick motion was quite small, barely noticeable; it was good. No compromises.

PREDICTABILITY OF RESPONSE

Initially the airplane response was just a little slow compared to what I would have liked to see for real fine control. The final response was a little slow in being achieved, but it wasn't oscillatory.

CONFIGURATION 1D
EVALUATION FLT 18 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the in-flight refueling was just not very solid if I can use that word. I really didn't feel that I had good fine control, but it was acceptable. I don't say that it was satisfactory. The tracking capability was only fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not really looked at.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Longitudinal control relative to the tanker was good. No problem there; not perfect, a little tendency to bobble up and down at a very slow rate. I did make the turn with him there for a short time and it was okay in the turn, but still just not as precise as I would have liked.

GOOD FEATURES

I could do the job, and certainly adapt to the airplane, so that I think it was an acceptable one from that standpoint.

OBJECTIONABLE FEATURES

The tendency to get a one- or two-cycle oscillation before getting to the basket and not having very precise control at the basket.

PRIMARY REASON FOR PILOT RATING

I think what I've seen we'll call minor but annoying. There was a slight tendency to get undesirable pilot-induced motions.

CONFIGURATION 1D REFUELING PILOT A PR 2 PIOR 1
EVALUATION FLT 19

ABILITY TO TRIM

Ability to trim was good; not super, but good.

STICK FORCES

Stick forces and motions were satisfactory; no reason to change them.

PREDICTABILITY OF RESPONSE

Predictability of airplane response was good. Initial response seemed to be good. I seemed to have good control over the final response.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was certainly good to excellent, and the tracking capability was good.

NORMAL ACCELERATION CONTROL

Normal acceleration control seemed to be good.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was likewise good.

GOOD FEATURES

I had real good control over the airplane; I could hook up at will.

CONFIGURATION 1D
EVALUATION FLT 19 (Cont.)

OBJECTIONABLE FEATURES

No real major objections. A couple of minor ones: I didn't quite seem to have that nice, precise touch that I would have liked for the sensitivity of response that would make it a really good airplane.

PRIMARY REASON FOR PILOT RATING

I certainly think it was good. Pilot compensation was not a factor. I had precision of control. There was no tendency for the pilot to introduce undesirable motions.

CONFIGURATION 1E WITH TGT PILOT A PR 8 PIOR 3 TR D
EVALUATION FLT 24

ABILITY TO TRIM

I thought the ability to trim was quite poor.

STICK FORCES

Stick forces were satisfactory; however, there was a real tendency for the forces to lighten when I put in an abrupt input and pulled any g with it. The g came on and overshot much more than I really wanted in the maneuvering task. Forces, however, were satisfactory. The stick motion was satisfactory.

PREDICTABILITY OF RESPONSE

The predictability of the airplane response to pilot input was very poor. The initial response was very slow coming on, but the final response was really the biggest problem. There was a real tendency to overcontrol, over g, the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I wasn't able to control the airplane with any degree of certainty during abrupt maneuvers, particularly when I wanted to pull a lot of g. There was no assurance that I was going to get the g that I wanted. Tracking capability was acceptable, but still not very good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was the really detrimental factor. I really felt as if I was going to overstress the airplane a lot of times, and I had to really watch what I was doing and check the stick forward to keep it from over g'ing. In the turns there was the same tendency to overcontrol anytime I tried to do anything abruptly. Once I got the airplane headed in the direction I wanted, it would stay there pretty well. So in a nice steady tracking maneuver I could hold the pipper on target a bit, but still not very well.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence was quite dramatic; it moved the nose of the airplane around quite a bit. So I thought the turbulence had quite a detrimental effect on the airplane.

GOOD FEATURES

Really none that I could see.

OBJECTIONABLE FEATURES

The tendency to overcontrol, the tendency to really feel as if you could break the airplane in the higher g maneuvers. I had to be very careful with my inputs. I had to check forward when the airplane started in a rapid maneuver so that I didn't get too much g.

CONFIGURATION 1E
EVALUATION FLT 24 (Cont.)

PRIMARY REASON FOR PILOT RATING

I didn't think the airplane was acceptable for the fighter mission. I think you have to worry about losing control on high g maneuvers because of the tendency to over g. Turbulence was especially bad; more effort was required, certainly a moderate deterioration of performance. There really weren't any pilot-induced oscillations, but certainly it fits into the category of undesirable motions.

CONFIGURATION 1E WITHOUT TGT PILOT A PR 8 PIOR 3.5 TR D
EVALUATION FLT 26

ABILITY TO TRIM

It was a very difficult airplane to trim; didn't want to hold its trim. It took a while to get it trimmed up and once I got it there, I wasn't able to keep it there very well.

STICK FORCES

Stick forces were okay. The big problem with the stick force per g was that it took a fair, sizable input to get the airplane to start and then it really took off on its own. I had to always, after initiating a positive g maneuver, push forward to stop the airplane from over g'ing. So, the stick forces were not very consistent in that they were heavy initially and lightened up in the final response. But I didn't really feel that I needed to try any other gear selection; I just didn't have very good control of the airplane. Stick motions were noticeable but acceptable. I found that I had to pump the stick a fair amount to damp out some of the pilot-induced oscillations, so I did notice that the stick was moving enough for it to be less than desirable.

PREDICTABILITY OF RESPONSE

The airplane response was very unpredictable. Initial response was quite sluggish and slow, and there was a real tendency to overcontrol the airplane in g so that the final response was completely unacceptable.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

The pitch attitude control and tracking capability were very poor. Anytime I tried to do anything tightly with the airplane, I would get into a pilot-induced oscillation.

NORMAL ACCELERATION CONTROL

Normal acceleration control was the thing that made the airplane completely unacceptable for the mission. The airplane really wanted to dig in and overshoot the desired g value; and for me it was very uncomfortable. So I found that normal acceleration control was a major detrimental aspect of this airplane. In steep turns the longitudinal control was poor. I would roll into a turn and stop the airplane, then apply a little back stick and the next thing I'd know, it would be digging in, causing quite a problem as I came around the turn.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances really made this airplane difficult to control; not so much because of the response of the airplane itself to the turbulence but because of the pilot's attempt to control the change in attitude. I continually overcontrolled during the random inputs. That is different from having the airplane itself really respond a lot to the random disturbance.

INSTRUMENT FLIGHT PROBLEMS

Trying to track, heads down in the cockpit, produced the same problems; doing things a little slowly helped me a little bit, but I still overcontrolled the airplane.

GOOD FEATURES

No really good features about the airplane.

CONFIGURATION 1E
EVALUATION 26 (Cont.)

OBJECTIONABLE FEATURES

The major objection was the strong tendency to overcontrol in g. There was a somewhat lesser tendency toward a pilot-induced oscillation when I tried to fly the airplane in a tight tracking maneuver. I did have to check forward on the stick anytime I made an abrupt positive maneuver; this was very disconcerting and made the airplane very difficult to fly.

PRIMARY REASON FOR PILOT RATING

I didn't think the airplane was acceptable for the mission. I think considerable pilot compensation was required to keep from over g'ing the airplane. Certainly for PIO's it was between the undesirable motions and oscillations when I attempted abrupt maneuvers. As far as the turbulence is concerned, certainly more effort was required and I think primarily because of my inputs.

CONFIGURATION 1E   REFUELING   PILOT A   PR 10   PIOR 5
EVALUATION FLT 17

ABILITY TO TRIM

Ability to trim was only fair, not very good.

STICK FORCES

Stick forces and motion were satisfactory. Stick motion was noticeable, however, because I caught myself pumping the stick trying to stop the rather severe pilot-induced oscillation that occurred when we got up close.

PREDICTABILITY OF RESPONSE

The airplane response was not at all predictable. Anytime I tried to track the basket or get close to it, I got into a PIO that was divergent as I got tighter in the control loop.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was completely unacceptable.

NORMAL ACCELERATION CONTROL

Normal acceleration control was poor. The airplane had a noticeable PIO tendency.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was likewise poor; I was going quite a few feet, I'll say +20 feet up and down behind the tanker.

GOOD FEATURES

I could fly it as long as I didn't try to do any tight tracking.

OBJECTIONABLE FEATURES

Anytime I got close to the tanker and tried to track the basket, I got into a quite noticeable and divergent PIO. The only way to stop it was to back off and abandon the task. I couldn't find any technique that kept me from getting into PIO.

PRIMARY REASON FOR PILOT RATING

For this task, I didn't think I could do the mission, it was not an acceptable airplane. I think controllability is going to be a question. Control might be lost if you try to accomplish the mission. I couldn't really get a refueling hook-up. If I had tried to get hooked up, I think I would have lost control of the airplane. The pilot-induced oscillations were divergent, and I could stop them by just abandoning the task.

CONFIGURATION 2A WITH TGT PILOT A PR 4 PIOR 2 TR B
EVALUATION FLT 29

ABILITY TO TRIM

Ability to trim was really quite good.

STICK FORCES

I thought the stick forces were quite satisfactory, and the stick motions barely noticeable; they were good. I saw no reason to try to reselect the gearing.

PREDICTABILITY OF RESPONSE

Initially I thought it was going to be a nice predictable airplane to fly; however, when I got in close there was just a slight tendency to bobble the airplane a little bit and that was fairly consistent throughout. It wasn't a continuous PIO type of thing but it was a kind of persistent bobbling tendency. In general I thought the maneuvering of the airplane was pretty good.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was only fair. I think you would get shells into the other airplane. I think you could do the job, but it was not in my estimation satisfactory. Tracking capability was somewhat degraded because of the tendency to bobble the airplane a little bit when trying to make corrections in close.

NORMAL ACCELERATION CONTROL

Normal acceleration control in general was quite good. There was no tendency to over g the airplane. During the turns in ACM, longitudinal control was good, with the same bobbling tendency mentioned before.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence seemed to have very little effect on the airplane; a little more effort required, but no significant deterioration of my performance.

GOOD FEATURES

A very maneuverable airplane to fly.

OBJECTIONABLE FEATURES

The only objectionable feature was the persistent bobble during the tracking task.

PRIMARY REASON FOR PILOT RATING

I would like to see it improved. There were some undesirable motions, and they were annoying.

CONFIGURATION 2A WITHOUT TGT PILOT A PR 3 PIOR 1.5 TR C
EVALUATION FLT 29

ABILITY TO TRIM

The ability to trim was quite good.

STICK FORCES

Stick forces were quite satisfactory. It was quite a maneuverable airplane, very enjoyable to fly. No second thoughts on the gearing. Stick motions were no problem, barely noticeable.

PREDICTABILITY OF RESPONSE

Initial response was quite fast, approaching abrupt, but I think I could live with that. In the final response, there was a tendency to get about one overshoot but the airplane was well damped; stopped right where I wanted it.

CONFIGURATION 2A
EVALUATION FLT 29 WITHOUT TGT (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I thought pitch attitude control and tracking capability were fair to good. A slight tendency to overshoot the target but once I would get it there and stop, it was surely well damped and stayed there pretty well.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good. It was really maneuverable. Longitudinal control in steep turns was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances seemed to have kind of a moderate effect. I guess "more effort required" and it reached down to a "minor deterioration of performance" with the random disturbance.

INSTRUMENT FLIGHT PROBLEMS

On the tracking maneuvers IFR, there was a tendency to overshoot the target quite noticeably, but I could bring it back and stop it where I wanted with no problem.

GOOD FEATURES

I liked the maneuvering capability of the airplane; tracking was only fair.

OBJECTIONABLE FEATURES

The tendency to overshoot the target at least once before it settled down.

PRIMARY REASON FOR PILOT RATING

I thought it was acceptable; actually it was satisfactory. There was a little more than I would have liked as far as overshooting the target; it was just not as good as I would have liked.

CONFIGURATION 2A REFUELING PILOT A PR 2.5 PIOR 1 TR A
EVALUATION FLT 16

ABILITY TO TRIM

I thought the trim was good.

STICK FORCES

Stick forces were good; a little light, but not overly sensitive. Stick motion was satisfactory.

PREDICTABILITY OF RESPONSE

The airplane response was quite predictable.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the in-flight refueling was quite good; no problem there at all. I could feel that the airplane was a little sensitive, but I seemed to adapt to that pretty well after the first run or so. No problem with the refueling hook-ups.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control was excellent.

GOOD FEATURES

Really good control with the airplane.

CONFIGURATION 2A
EVALUATION FLT 16 (Cont.)

OBJECTIONABLE FEATURES

If anything, a slight objection to the sensitivity of the airplane when in close.

PRIMARY REASON FOR PILOT RATING

The sensitivity in close was a little bit unpleasant.

CONFIGURATION 2C WITH TGT PILOT A PR 4.5 PIOR 2 TR C
EVALUATION FLT 7

ABILITY TO TRIM

Ability to trim was not too bad; it held the trim reasonably well.

STICK FORCES

Stick forces were quite comfortable and light. As a matter of fact I didn't see much variation on stick force per g. It was quite satisfactory to me. Stick motion was likewise satisfactory, very little stick motion that I could see. I saw no reason to reselect the gear ratio.

PREDICTABILITY OF RESPONSE

The airplane seemed to be reasonably predictable to pilot inputs, and it was a good maneuvering airplane. I could pull g with it quite nicely and maneuver around the sky; I enjoyed it.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the ACM was only fair, however, and it fed into the tracking capability. The problem that I really had was a tendency for an occasional lightly damped oscillation. For lack of a better word, it "nibbled" at a pilot-induced oscillation so that every now and then I would get a ripple in the airplane. I think it sufficient enough to say that the tracking was not good; it should be improved.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good, pulling g was no problem. There was a little bit of a tendency to get a structural vibration when pulling g. Longitudinal control during the turns was good with this occasional tendency to get a bobble or nibble at a PIO.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence didn't have a major effect on the airplane, but it did increase the tendency for this nibbly type oscillation mentioned before.

GOOD FEATURES

I liked the maneuvering capabilities.

OBJECTIONABLE FEATURES

I didn't particularly like the tendency for this nibbly type pilot-induced oscillation, although that is really not a good word for it. It was just kind of a movement in the nose; it made a 3- or 4-sec nibble at an oscillation that I didn't like.

PRIMARY REASON FOR PILOT RATING

I think that it was in the moderately objectionable category. I didn't think that it was a particularly good airplane; it was not satisfactory as it was. I really couldn't compensate for that incipient PIO. I am just trying to say that the performance wasn't as good as I would have liked; it needed to be improved. In turbulence, more effort was required, but there was only a moderate deterioration in performance.

CONFIGURATION 2C WITHOUT TGT PILOT A PIOR 1.2 PR 3 TR B
EVALUATION FLT 28

ABILITY TO TRIM

Ability to trim was really very good.

STICK FORCES

The forces were okay. When I was maneuvering, I felt the stick forces were good. They were nice and light, and I had no second thoughts on the gearing selection. Stick motions were barely noticeable, and I considered that good.

PREDICTABILITY OF RESPONSE

The initial response was quite abrupt, quite rapid, but there was only a small tendency to overshoot the target. I could make nice, small, fine corrections, using almost fingertip control to move the pipper where I wanted. Even though the initial response was abrupt, final response was quite well damped, and it usually stopped with about one overshoot.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

The pitch attitude control was satisfactory. Tracking capability was not quite as good as I would have liked, but I was able to do a reasonable job with it.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good. It was a good airplane for general maneuvering, good g control. Control in steep turns was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbance seemed to have only a minor effect on my performance; it did cause a little more effort, but nothing dramatic.

INSTRUMENT FLIGHT PROBLEMS

It wasn't too different from flying it VFR. It had a tendency for about one overshoot. It was noticeable but I had seen that VFR as well. On the random tracking task, the performance was pretty good, and the discrete tracking task I also thought was good.

GOOD FEATURES

The tracking capability was certainly good enough to be called satisfactory. The general maneuvering capability was also good.

OBJECTIONABLE FEATURES

One minor objection was the tendency for the initial response to be a little bit abrupt for the tracking; during tracking it would overshoot the target a small amount before settling down. I could fly the airplane normally except that I did want to put in easy initial inputs.

PRIMARY REASON FOR PILOT RATING

The airplane was acceptable and I think it was satisfactory. There was a slight PIO tendency but nothing that I couldn't live with. Turbulence caused a little more effort, but no significant deterioration.

CONFIGURATION 2C   WITHOUT TGT   PILOT B   PR 4   PIOR 2   TR C
EVALUATION FLT 10

ABILITY TO TRIM

The trim button is rather large, and when I put my thumb on it comfortably to make a trim motion I seemed to bobble the stick. I think it was just because of the size of the trim button and because of the trim forces.

STICK FORCES

Stick forces were okay. I wouldn't want another gearing for the task I was doing. Stick motions were relatively small and comfortable.

PREDICTABILITY OF RESPONSE

Around the trim point, the airplane was a little greasy on the response. Once I put on a little bit of g load, 2 to 2-1/2 g's, I was much better able to predict where the nose would end up when I wanted to stop it.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability at less than 2 g's was a little bit bobbly. It might have been me or the airplane. When I got above 2 g's, between 2 and 3-1/2, it was much easier to track; it seemed easier to hold on the target.

NORMAL ACCELERATION CONTROL

VFR, it was pretty easy to hold the g. In IFR conditions, I could feel the nose of the airplane bobbling around, and I would get about a 0.1-g disturbance on the g meter.

EFFECTS OF RANDOM DISTURBANCE INPUTS

The effect of the random disturbance inputs I saw was just like a little bit of turbulence, and didn't seem to bother me at all. It didn't seem to disturb the tracking task.

INSTRUMENT FLIGHT PROBLEMS

The only thing that showed up IFR that didn't show up VFR was that in pitch I could feel myself move the airplane responding to the tracking needle. I couldn't see it on any of the instruments in the cockpit, which is kind of a short-circuit between the "seat of the pants" senses and the eyeballs. It didn't seem to pose any problem that I know of under sustained IFR conditions.

GOOD FEATURES

It was very responsive in pitch, and I think once you have flown the airplane or learned how to brace your arm against your leg, you could track very nicely with it. As I said, it was very responsive; it seemed as if I could put the nose where I wanted to.

OBJECTIONABLE FEATURES

I didn't see any objectionable features that would detract from the mission, the tracking mission. I would say it was not satisfactory without improvement. I believe that it had a minor but annoying deficiency, the plus 1 g, minus half a g around trim. It was very greasy; it took considerable pilot attention to keep the nose tracking where I wanted it. When the g load built up a little higher, I had a better feeling for the longitudinal control and could nail down the longitudinal nose position. In turbulence, there was no additional effort required and the deterioration of task was minor. Undesirable motions did tend to occur but could be prevented or eliminated by pilot technique.

CONFIGURATION 2D WITH TGT PILOT A PR 3 PIOR 1 TR C
EVALUATION FLT 20

ABILITY TO TRIM

The ability to trim was quite good.

STICK FORCES

Stick forces and motion were quite satisfactory.

PREDICTABILITY OF RESPONSE

The predictability of the airplane respcnse to pilot inputs was pretty good. Initially the airplane seemed to respond a little rapidly. It seemed to be well damped in the final response, and I was able to stop the nose where I wanted.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

During ACM I could hold it right on the target reasonably well. There was little tendency to bobble the airplane ever so slightly. The tracking capability was not perfect, but was satisfactory.

NORMAL ACCELERATION CONTROL

A nice maneuverable airplane.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence pushed the nose of the airplane around quite a bit. I was a little surprised it was that bad. I think it is something that you could live with.

GOOD FEATURES

The tracking capability was good; not excellent, but it was good.

OBJECTIONABLE FEATURES

The slight tendency to bobble the airplane during tight tracking. It was particularly noticeable in turbulence.

PRIMARY REASON FOR PILOT RATING

I would say a good airplane; it was satisfactory. Normal pilot compensation required to make it a good airplane. I didn't like the slight tendency to bobble the airplane. I think the airplane was sensitive to turbulence. Certainly more effort was required in turbulence with at least a moderate deterioration in performance.

CONFIGURATION 2D WITH TGT PILOT A PR 2.5 PIOR 1 TR B
EVALUATION FLT 22

ABILITY TO TRIM

Ability to trim was very good.

STICK FORCES

Stick forces and motion were satisfactory; very pleasurable airplane to fly.

PREDICTABILITY OF RESPONSE

The response to pilot inputs was quite predictable.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the air combat maneuvering was good. I felt that I had good tracking capability; I could keep the pipper pretty close to the target and not have any problems.

NORMAL ACCELERATION CONTROL

Normal acceleration control was good; a real pleasurable airplane to maneuver. Longitudinal control in turns during the ACM was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence didn't seem to have much effect. A little more effort was required, but no significant deterioration in my task performance.

GOOD FEATURES

I liked the tracking capability. I also liked the normal acceleration control.

OBJECTIONABLE FEATURES

One minor objection, a tendency to be a little bit sensitive. Just a light tendency, during the tracking, to wiggle the nose a bit more than I would like.

PRIMARY REASON FOR PILOT RATING

I think it was a satisfactory airplane. It was not quite as good as I would have liked, but there was no real pilot compensation required for good performance.

CONFIGURATION 2D   WITH TGT   PILOT B   PR 2   PIOR 1   TR A
EVALUATION FLT 13

ABILITY TO TRIM

No problem with trim.

STICK FORCES

Stick forces were satisfactory.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response to pilot inputs was very good. The nose motion was tied very closely to the stick; I could just pull the stick and move the nose, then stop moving the stick and the nose stopped. It was very nice to track with.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I thought pitch attitude control was good. It was very nice, easy to control, very much fun to track, and a very good tracking airplane. In the beginning, I saw a little bobbling and a little sensitivity in pitch, but I got a little better with a little practice. I needed that sensitivity to keep the pipper rolling up and down the target fuselage.

NORMAL ACCELERATION CONTROL

During acquisition there was no problem with normal acceleration control up to 3-1/2 g's. Extrapolating that out at the 7 g's, it doesn't seem that we would have any problem.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances were bothersome to me, but I didn't see any effect; I totally feel that it was me bouncing the airplane as much as the turbulence.

GOOD FEATURES

It was a very good tracking airplane. It was easy to acquire the target, pull the trigger where I wanted it, then keep the pipper on the target. I think the more you see of this airplane the better you would get with your tracking.

OBJECTIONABLE FEATURES

I saw no objectionable features.

CONFIGURATION 2D
EVALUATION FLT 13 (Cont.)

PRIMARY REASON FOR PILOT RATING

I thought it was satisfactory without improvement. There were no visible deficiencies. I don't think pilot compensation was a factor for getting the tracking performance that we were looking for. There was no significant increase, no significant deterioration in the presence of random disturbances. There was no tendency for pilot-induced undesirable motions.

CONFIGURATION 2D WITHOUT TGT PILOT A PR 3 PIOR 1 TR A
EVALUATION FLT 8

ABILITY TO TRIM

Ability to trim was excellent.

STICK FORCES

Stick forces and motions were quite comfortable, and I had no second thoughts on gearing selection.

PREDICTABILITY OF RESPONSE

The initial response was really quite good. The airplane response came on smoothly. I could see no tendency to lag or be behind the airplane; I thought that was good. In the final response, I invariably found myself overcontrolling just a little. I would like to see it better, but it wasn't a very detrimental thing. Pulling g and maneuvering the airplane was quite good.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability was fair. Starting off, I had a bit of a nose bobbling problem. There was a tendency to overcontrol the airplane just past the g value, for instance, that I wanted; so my pitch attitude control wasn't as perfect as I would have liked although I still thought it was good. Tracking capability seemed to be good; in particular in the tracking task. There was a tendency to just overshoot the needle ever so slightly. I thought that the tracking capability was acceptable.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good; symmetrical pull ups and horizontal turns, good g control. In steep turns I had real good g control as well.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances affected the airplane a little bit, but nothing really major. I found that it did disturb the nose a little bit but in general I thought I had good control in the random disturbances; it wasn't much of a problem.

INSTRUMENT FLIGHT PROBLEMS

IFR I didn't see any problems that didn't show up VFR.

GOOD FEATURES

I thought, in general, the maneuvering capability was excellent. I liked the compatibility of the stick forces and stick motions. I liked the stick forces themselves.

OBJECTIONABLE FEATURES

A mild objection was the slight tendency to overcontrol when doing the tight tracking task, but I was able to track the needle quite well.

PRIMARY REASON FOR PILOT RATING

I'm willing to say the airplane was satisfactory. I think the small overshooting tendency that I saw fell into the moderate and unpleasant deficiency category but still acceptable. I thought the airplane was relatively insensitive to the turbulence.

CONFIGURATION 2D WITHOUT TGT PILOT B PR 2 PIOR 1 TR B
EVALUATION FLT 11

ABILITY TO TRIM

It was easy to trim.

STICK FORCES

Stick forces were okay; they weren't bothersome at all, and they weren't heavy at the high g end. Stick motions were acceptable.

PREDICTABILITY OF RESPONSE

It was a very nice airplane to fly. It was easy to predict what response you were going to get between the stick and the nose of the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

It was very easy to stop the airplane on a desired attitude or in a bank turning or pitching attitude.

NORMAL ACCELERATION CONTROL

Normal acceleration control was good. You could go to and maintain a g with no overshoots. Longitudinal control in steep turns was good, and it was very easy to move the pipper. I wasn't using the pipper, but I could move the nose of the airplane and stop it precisely where I wanted.

EFFECTS OF RANDOM DISTURBANCE INPUTS

It was no more than just normal turbulence so it didn't take any different technique. It seemed to make the task a little more difficult, but it was easy to control.

GOOD FEATURES

The stick forces were comfortable up to 3-1/2 g's. I could stop the nose wherever I wanted, which is extremely good for tracking. It was very quick from trim to move the nose, and there were no overshoots when I got to the new attitude.

OBJECTIONABLE FEATURES

I saw no objectionable features.

PRIMARY REASON FOR PILOT RATING

I would rate it good with negligible deficiencies for the task of tracking another aircraft. With turbulence more effort was required, but there was no significant deterioration in performance. There was no tendency for the pilot to induce undesirable motions.

CONFIGURATION 2D REFUELING PILOT A PR 1 PIOR 1
EVALUATION FLT 17

ABILITY TO TRIM

Trim was good.

STICK FORCES

Stick forces were satisfactory, and stick motion was barely noticeable. No reselection of gearing was required.

PREDICTABILITY OF RESPONSE

I really liked that one; I could "think" the airplane right to the position I wanted. Initial and final responses were both good.

CONFIGURATION 2D
EVALUATION FLT 17 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I had excellent pitch attitude control during the in-flight refueling.

NORMAL ACCELERATION CONTROL

Acceleration was normal; absolutely no problem.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was really excellent. As for longitudinal control in turns, I did my first hook-up with this airplane in a turn and I had excellent control.

GOOD FEATURES

I just had real fine control throughout. I can't see where I would like to improve anything. Nice, smooth, fine control; I hardly had to even think about moving the stick to get the probe where I wanted it to go.

OBJECTIONABLE FEATURES

No objections at all.

PRIMARY REASON FOR PILOT RATING

It was an excellent, highly desirable airplane for in-flight refueling, because I could just think the airplane to the position that I wanted. I could fly up, position the probe in the basket, then hook up at will.

CONFIGURATION 2D REFUELING PILOT A PR 1 PIOR 1
EVALUATION FLT 18

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces were light but quite satisfactory, and stick motion was barely noticeable. I liked that; I didn't even feel like I was moving the stick. I could just kind of think the airplane into position, and that's really great.

PREDICTABILITY OF RESPONSE

Predictability of airplane response to pilot inputs was really good.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was really excellent. I could really put the probe right where I wanted it. The tracking capability was good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not really checked.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was excellent.

GOOD FEATURES

I could really put that probe right where I wanted. I could drive up there and stop. I could just pick out the center portion of the basket and insert the probe perfectly.

CONFIGURATION 2D
EVALUATION FLT 18 (Cont.)

OBJECTIONABLE FEATURES

No objectionable features.

PRIMARY REASON FOR PILOT RATING

It was a real good airplane for this mission; I could just do exactly what I wanted to do with the airplane.

CONFIGURATION 2D   REFUELING   PILOT A   PR 2   PIOR 1
EVALUATION FLT 19

ABILITY TO TRIM

Ability to trim was pretty good.

STICK FORCES

Stick forces were satisfactory. Stick motion was also satisfactory, with very small motions being required.

PREDICTABILITY OF RESPONSE

The initial response of the airplane was reasonably snappy, but with good precision. Final response was predictable. Initial response was perhaps a little too snappy because there was a little bit of a tendency to bobble the airplane but it was very slow.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during refueling was good; it didn't create any problems for me there. Tracking the drogue was good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not really tested.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was good. I didn't really look at refueling in turns, but I think it would be good.

GOOD FEATURES

It was a good flying airplane, and good for the in-flight refueling mission. I adjusted a little bit to the pitch sensitivity.

OBJECTIONABLE FEATURES

It had a tendency to bobble and not have quite the precision of control I wanted, but that was very minor.

PRIMARY REASON FOR PILOT RATING

I think it certainly was an acceptable airplane. I think it was good, and that pilot compensation was not really a factor to get desired performance. There was no tendency to induce undesirable motions.

CONFIGURATION 2E   WITH FGT   PILOT A   PR 7   PIOR 4   TR C
EVALUATION FLT 6

ABILITY TO TRIM

Ability to trim seemed to be okay.

CONFIGURATION 2E
EVALUATION FLT 6 (Cont)

STICK FORCES

Stick forces were quite light and stick motion was quite small. I didn't see any reason to reselect the gear ratio. The forces were good for maneuvering but poor for tracking.

PREDICTABILITY OF RESPONSE

The initial response seemed to be a little slow coming on, but I could pull up and get g with the airplane. When I tried to track, I almost had continuous pilot-induced oscillations.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the tracking was very poor. Tracking capability was likewise very poor. There was a strong tendency to just continuously oscillate when trying to track.

NORMAL ACCELERATION CONTROL

Normal acceleration control for gross maneuvers wasn't all that bad. Longitudinal control in turns during the ACM was very poor. When I tried to track the target I just had a continuous small oscillation going.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence didn't seem to give me as much of a problem as I had anticipated, but it emphasized the tendency to oscillate, since the airplane kept getting disturbed. Unless I would attempt to stop it, it would continue to oscillate. So it was degraded in turbulence.

GOOD FEATURES

No good features.

OBJECTIONABLE FEATURES

Objectionable features included the real strong tendency for the airplane to oscillate as I tracked. It was not a divergent thing and was not a controllability problem, but it surely destroyed the ability to be an attack airplane. More effort was required in turbulence but only minor deterioration was noted. There were pilot-induced oscillations and I could stop them, but I had to abandon the task.

CONFIGURATION 2E WITH TGT PILOT A PR 6 PIOR 4 TR C
EVALUATION FLT 20

ABILITY TO TRIM

The trim was good.

STICK FORCES

Stick forces were satisfactory. Stick motion was satisfactory but noticeable because I found myself pumping the stick.

PREDICTABILITY OF RESPONSE

The initial response was just a little slow. I wouldn't get the response I wanted, and I ended up overcontrolling and bobbling the airplane. If I just made large gross inputs I could pull up the nose and not set up the oscillation, but when I attempted tight tracking I ended up with an oscillation. So, neither the initial not the final response was as good as I would have liked.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the ACM was poor. It was interesting because sometimes I would set up an oscillation and other times I wouldn't, but in general, it was not a very good tracking airplane. The attitude control during ACM was poor with a tendency to induce oscillations. The oscillations destroyed quite a bit of my target tracking. Tracking capability was poor. When tracking, pilot-induced oscillations were quite noticeably excited. I think you might possibly get a few bullets in the target, but it really was not very good.

CONFIGURATION 2E
EVALUATION FLT 20 (Cont.)

NORMAL ACCELERATION CONTROL

Normal acceleration control seemed to be one of the better features; I could pull g and maneuver the airplane reasonably well. During the turns I noticed again that when I attempted tight control I would get a pilot-induced oscillation.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence and random disturbances didn't seem to have a real major effect on the airplane. It did cause me to work harder, certainly more effort was required but the deterioration from an already poor performance was not any more than minor.

GOOD FEATURES

I could really maneuver the airplane quite well. I could get into a tracking position.

OBJECTIONABLE FEATURES

I could track but it was in a continuous oscillation.

PRIMARY REASON FOR PILOT RATING

I am willing to say that the airplane was acceptable, but I found that the tendency to set up a pilot-induced oscillation while tracking, even though of small amplitude, was very objectionable and would have to be fixed. The airplane does have a PIO tendency; oscillations did develop when I attempted the abrupt maneuvers.

CONFIGURATION 2F WITH FGT PILOT A PR 7 PIOR 4 TR D
EVALUATION FLT 4

ABILITY TO TRIM

Ability to trim was pretty fair.

STICK FORCES

Stick forces were satisfactory. I didn't think they were too light or heavy. Stick motion was satisfactory.

PREDICTABILITY OF RESPONSE

Predictability of airplane response to inputs was very interesting. I had a good maneuvering airplane and I could pull g and maneuver well. I thought the airplane response was quite predictable. When I attempted to track with the airplane, though, I set up a quite noticeable small-amplitude, pilot-induced oscillation. It really took me by surprise. So, the final response for maneuvering was pretty good as was the initial, but the tracking was very poor .

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was poor; anytime I tried to make a small correction, I set up an oscillation. When I was doing gross maneuvers, I could drive around, pull g or anything I wanted to, but I couldn't track. Tracking capability was unacceptable.

NORMAL ACCELERATION CONTROL

Normal acceleration control for large maneuvering was good; small maneuvering was very poor.

EFFECTS OF RANDOM DISTURBANCE INPUTS

When I tried to make small corrections to stop the response to turbulence, I set up pilot-induced oscillations.

GOOD FEATURES

The airplane was excellent for maneuvering.

CONFIGURATION 2F
EVALUATION FLT 4 (Cont.)

OBJECTIONABLE FEATURES

I had strong objections to the PIO tendency in the tight tracking maneuvers.

PRIMARY REASON FOR PILOT RATING

I could not track and I don't think I could adequately perform the mission. The only way I could stop the PIO's was to abandon the task. Turbulence did affect the task accomplishment to the extent of more effort required with a moderate deterioration of task.

CONFIGURATION 2F WITHOUT TGT PILOT A PR 7 PIOR 4 TR D
EVALUATION FLT 26

ABILITY TO TRIM

Ability to trim was really pretty good.

STICK FORCES

Stick forces were quite satisfactory. No second thoughts on the gearing. Stick motions were a little bit noticeable because the airplane was quite oscillatory under certain tracking maneuvers and I found myself noticeably adding to this, pumping the stick back and forth so that the motions were acceptable but still not very good.

PREDICTABILITY OF RESPONSE

The initial response tended to be just a little slow and the final response, when I tried to stop it on the target, was quite oscillatory. So, in general, the response predictability was not very good.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability were quite poor; they were unacceptable. I would get a 5- or 6-cycle oscillation anytime I tried to stop the airplane on a target.

NORMAL ACCELERATION CONTROL

The normal acceleration control was quite good for normal maneuvering. It was a very maneuverable airplane, very enjoyable to fly. I felt that the longitudinal control in steep turns was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

When I tried to control the response to random disturbances in a tight tracking task, I had a tendency to get a 5- or 6-cycle oscillation; so in general, my control capability in the presence of random disturbance was poor.

INSTRUMENT FLIGHT PROBLEMS

Attempting the tracking tasks, heads down, I was almost in a continuous oscillation. So it was more difficult flying the tight tracking task than it was heads up VFR.

GOOD FEATURES

The maneuvering capability in general was quite good.

OBJECTIONABLE FEATURES

The tendency toward a 5- or 6-cycle oscillation when I tried to do something with a tight tracking task was objectionable. Random disturbance tracking was very poor. I had to try to impart damping to the system and found myself pumping the stick quite a bit.

PRIMARY REASON FOR PILOT RATING

I think it was unacceptable.

CONFIGURATION 2H WITH TGT PILOT A PR 4 PIOR 1.5 TR C
EVALUATION FLT 22

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces and motions were satisfactory.

PREDICTABILITY OF RESPONSE

The response was not quite as predictable as I would have liked. A little bit slow initially. Final response, however, was fair.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was fair. A little tendency for the pipper to wander more than anything else. Tracking was only fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was good. Longitudinal control during turns, during ACM, was fair.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence had a moderate effect on the airplane; I'd say more effort required, at least a moderate deterioration in performance.

GOOD FEATURES

I could track, but not as well as I would have liked.

OBJECTIONABLE FEATURES

The tendency to bobble or oscillate the airplane in the tracking was objectionable.

CONFIGURATION 2J WITH TGT PILOT A PR 5 PIOR 2 TR D
EVALUATION FLT 21

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

The stick forces were satisfactory and the stick motions were satisfactory, but a bit noticeable.

PREDICTABILITY OF RESPONSE

I had a difficult time with this one. Sometimes the airplane seemed to track pretty well, but when I would try to make a correction, the airplane moved very slowly. Occasionally, I would get a one- or two-cycle pitch oscillation. It seemed that the airplane never responded very fast, so the predictability of the airplane response didn't seem very good. The airplane was very slow initially, and I tended to overdrive it. I was not able to be as precise with the airplane as I would have liked.

CONFIGURATION 2J
EVALUATION FLT 21 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the air combat maneuvering seemed to be pretty good with no real specific problems. I felt that I could track the target, but just never felt very comfortable about it.

NORMAL ACCELERATION CONTROL

Normal acceleration control wasn't as good as I would have liked, but I had good g capability and I had no feeling that I was going to over g the airplane, although my tracking capability was only fair. Longitudinal control during the turns was fair to poor. During ACM I thought I was able to track the airplane acceptably.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence seemed to have quite a dramatic effect on the airplane, moving the nose quite a bit; I really was behind the airplane all the time when in the turbulence, and never able to keep it on the target to my satisfaction.

GOOD FEATURES

It was a good maneuverable airplane and I could track acceptably.

OBJECTIONABLE FEATURES

The slowness of the airplane was objectionable, as was imprecision when trying to put the nose precisely where I wanted. I seemed to get worse with it the more I flew it.

PRIMARY REASON FOR PILOT RATING

The deficiencies that I've listed were moderately objectionable; I didn't have good precision and there was a slight tendency to oscillate. I thought it was a really poor plane in turbulence, and more effort was required with a deterioration in task.

CONFIGURATION 2J WITHOUT TGT PILOT A PR 5 PIOR 1.5 TR B
EVALUATION FLT 27

ABILITY TO TRIM

Ability to trim was fair. It really wasn't good, but it wasn't particularly bad.

STICK FORCES

Stick forces seemed to be a little heavy initially, and I thought there was a slight tendency to dig in -- not a lot, but I did overcontrol in g a little bit. I was really concerned about this because I flew it longer than normal, and still didn't end up knowing that much about it. I thought the stick forces were heavy initially, but I didn't think I would like to change them, because if I had I would have found that they were too light in the final response. Stick motions were okay. It was noticeable that there was a slight hesitation between a stick input and the airplane stick motions; so the stick motions were noticeable, at least in the initial input, but they were still okay.

PREDICTABILITY OF RESPONSE

Initially the airplane had a noticeable delay. I could see it, and when it "took off" at what I considered to be a fairly reasonable rate, I could (VFR) stop it reasonably well, pretty much where I wanted it. So I thought the initial response was okay. Final response was certainly well damped and my only concern there was how well I could stop the nose where I wanted it. Certainly it wasn't perfect tracking by any means but not really bad either.

CONFIGURATION 2J
EVALUATION 27 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability were only fair. I just couldn't make those nice, fine adjustments that I wanted, but I still thought that I could track.

NORMAL ACCELERATION CONTROL

Normal acceleration control was pretty good in the steady state. I had a bit of a tendency to overcontrol or dig in when doing things abruptly. Longitudinal control in steep turns was good. I did notice that in a steep turn, I could move the stick back and forth and there seemed to be kind of a deadband without anything happening. But I tended to have good g control and felt that I could probably track another airplane in the turn.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances seemed to have only a minor effect on the airplane. However, there was a very small amplitude response without any real disturbance of the airplane, so I didn't feel that the random disturbance affected my performance very much.

INSTRUMENT FLIGHT PROBLEMS

IFR, my tracking using the heads down display wasn't as good as I thought it was VFR. There was a tendency to overshoot and undershoot before I could get settled down on the needle. So tracking the airplane using the display was more difficult and not as precise as it was in the VFR task.

GOOD FEATURES

There were no really good features about the airplane. I felt that the tracking performance and the ability to control the airplane in steep turns were both only fair.

OBJECTIONABLE FEATURES

There were the slight tendency to dig in and the slight tendency to overcontrol during the tight tracking maneuver, but nothing really good or bad. There was an initial delay; when I made an input, I would find myself putting in a larger input initially and then backing off a little bit to keep from overcontrolling.

PRIMARY REASON FOR PILOT RATING

I wouldn't say that it was acceptable; I thought it was not satisfactory. There was some tendency toward undesirable motions upon abrupt pilot inputs, but what I saw was not too bad.

CONFIGURATION 2J REFUELING PILOT A PR 8 PIOR 4.5
EVALUATION FLT 19

ABILITY TO TRIM

I never even really tried to trim.

STICK FORCES

Stick forces and motions were unsatisfactory. The motion was noticeable because I ended up pumping the stick quite a bit while I was trying to hook up, and very definite pilot-induced oscillations would increase as I increased my tracking gain.

PREDICTABILITY OF RESPONSE

The airplane response itself seemed to be very slow initially, and final response was somewhat unpredictable, so I really didn't have very good control of the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during refueling was very, very poor. There was no way that I was going to get hooked up, so the tracking capability of the drogue was very poor.

NORMAL ACCELERATION CONTROL

Just what little I saw was poor.

CONFIGURATION 2J
EVALUATION FLT 19 (Cont.)

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was a function of my gain or how close I was to the basket. The closer I got, the worse PIO became. In fact there was no PIO until I got about 2-3 ft from the basket, and then I got a quite large, somewhat divergent oscillation of the nose.

GOOD FEATURES

The only good feature that I could see was that I could regain control simply by reducing my gain and backing off. I could fly the airplane straight and level; I just could not do the tight tracking task.

OBJECTIONABLE FEATURES

When in very close to the basket and attempting to hook up, I got pilot-induced oscillations that increased as I got closer. I had to abandon the task, back off, and just freeze the stick, or reduce my gain to stop the PIO's .

PRIMARY REASON FOR PILOT RATING

The airplane was not acceptable. I think certainly pilot compensation was required for control when I was in close. All I had to do was back off; I don't think I would have ever lost control, although I have already admitted that I could not do the mission. I thought the PIO's become divergent.

CONFIGURATION 3A   WITH TGT   PILOT A   PR 7   PIOR 4   TR E
EVALUATION FLT 6

ABILITY TO TRIM

Ability to trim was really quite good. It would stay right where I put it.

STICK FORCES

Stick forces were satisfactory. They were nice and light, but there was a problem. Every time I grabbed the stick there was a high-frequency, structural type vibration in the airplane. It was uncomfortable. It went away when I released the stick. Stick motion itself was satisfactory; I didn't see any reason to reselect the gear ratio.

PREDICTABILITY OF RESPONSE

I always got a real high-frequency vibration anytime I made an abrupt input, but it damped out reasonably fast and I could maneuver the airplane. So the initial response was bothersome but the final response was predictable in that I could maneuver the airplane, with a reasonably accurate g capability.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was ridiculous, quite oscillatory. It would just sit there with a real high-frequency, relatively low-amplitude oscillation when I attempted to track. The tracking capability was very poor.

NORMAL ACCELERATION CONTROL

Normal acceleration control wasn't bad; I could pull g, and maneuver reasonably well. The simulation itself was a little bit compromised because of the quite high structural noise involved. Longitudinal control during turns, when I was not tracking, was okay. I could hold g fine, but when trying to track I had a nearly constant, low-amplitude, high-frequency PIO.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence really had a dramatic effect on the airplane, and made it quite oscillatory and considerably poorer in turbulence than it was out of turbulence.

CONFIGURATION 3A
EVALUATION FLT 6 (Cont.)

GOOD FEATURES

I didn't feel as if I were going to lose control of the airplane; all I had to do was stop what I was doing and the oscillations would go away. So I considered that good.

OBJECTIONABLE FEATURES

I really couldn't do the job. Trying to track tightly, all I did was sit there with a high-frequency, low-amplitude oscillation. I really had to back off on my gain to stop the oscillation, so that I couldn't really do the job in my estimation.

PRIMARY REASON FOR PILOT RATING

I thought that adequate performance was not attainable; controllability, however, was not in question. Everytime I tried to do anything, I got an oscillation that I could reduce by stopping the task. Primary reason for the rating was the quite devastating pilot-induced oscillations. I really thought turbulence was bad. More effort was required, certainly a moderate deterioration in turbulence.

CONFIGURATION 3D WITH TGT PILOT A PR 6 PIOR 3 TR F
EVALUATION FLT 3

ABILITY TO TRIM

The ability to trim was good.

STICK FORCES

The stick forces were quite satisfactory; nice and light, as I like. The stick motion was not noticeable; therefore, I considered it satisfactory. I didn't really see any need to compromise on the elevator gearing; I liked it.

PREDICTABILITY OF RESPONSE

I had a tendency to overshoot or overcontrol the airplane in pitch. This showed up very much in the tracking, and my tracking wasn't very good. The airplane started out okay initially, when I made an input, but the response tended to get a little larger than I had bargained for. Nothing dangerous, but it did create some difficulty for me.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

During the air combat maneuvering, attitude control was not as good as I would have liked. I couldn't really keep the pipper on the target and I think it was a two-part problem. It was longitudinal mostly and a little bit of lateral; I just wasn't very good at it. Tracking capability was poor, just too slow for me to be able to get the airplane on the target. I couldn't make fast enough corrections to put the airplane back where I wanted it. I had a tendency to use quite a bit of rudder to make the airplane track where I wanted it to.

NORMAL ACCELERATION CONTROL

There was a tendency to overcontrol the airplane a little, and not to be able to track well. I could not position the airplane nose where I wanted.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence really had a dramatic effect. It pushed the airplane all over the sky. The slow response of the airplane to my inputs, and the quite rapid response to the turbulence, made it difficult to counter the effects of the random disturbance inputs.

GOOD FEATURES

I could fly the airplane around without any fear of breaking it or over g'ing it.

CONFIGURATION 3D
EVALUATION FLT 3 (Cont.)

OBJECTIONABLE FEATURES

It wasn't a very tight airplane for tracking. I found that I couldn't track the target to my satisfaction. There was a slight tendency to overcontrol in g.

PRIMARY REASON FOR PILOT RATING

Even with all these deficiencies, I am still willing to admit that I could track with the airplane although I found it very objectionable. I think I could shoot another airplane down, but I wouldn't be very good at it. It required a lot of pilot compensation to make the airplane do what I wanted. I got undesirable motions when initiating maneuvers. Turbulence was really bad, certainly down in the "best efforts required" because of quite significant deterioration in the task.

CONFIGURATION 4A WITH TGT PILOT A PR 4 PIOR 2 TR D
EVALUATION FLT 20

ABILITY TO TRIM

The ability to trim was good.

STICK FORCES

Stick forces and motion were satisfactory. The motion was a bit noticeable; I could feel myself having to impart a little damping to the system.

PREDICTABILITY OF RESPONSE

Predictability of the initial response was good; seemed to be a fairly snappy airplane. There was a bit of a tendency to oscillate in the final response.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was fair. When I attempted to track tightly, I got a very slight oscillation. I couldn't keep the pipper right where I wanted it. Pitch attitude, although not good, was certainly acceptable. Tracking capability was only fair. There was a tendency to bobble, or get a very small oscillation of the pipper on the target, but it was minor.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good, and I had good g control. Longitudinal control in turns was good. During the ACM tracking there was still a tendency to oscillate or bobble the airplane a little bit which was not really very good but still acceptable.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence seemed to have a fairly pronounced effect on the airplane, moved it around quite a bit. The degradation due to random disturbance was more than just a minor amount, I'd say down to a moderate degradation with more effort required.

GOOD FEATURES

I could track with the airplane even though it wasn't very good. I had good g capability and good maneuvering capability.

OBJECTIONABLE FEATURES

A slight tendency to be unable to keep the pipper on the target. Even though the bobble was very small, I think it should be eliminated.

PRIMARY REASON FOR PILOT RATING

What I saw was minor but annoying; it required some pilot compensation and needs to be fixed in order to be satisfactory. More effort was required and a moderate deterioration of performance occurred with random disturbances. I got some undesirable motions with pilot inputs, but they were not really too bad.

CONFIGURATION 4A WITHOUT TARGET PILOT A PR 5 PIOR 3 TR C
EVALUATION FLT 28

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces were good and I had no second thoughts on the gear selection. Stick motions were barely noticeable and I thought they were good.

PREDICTABILITY OF RESPONSE

The initial response was pretty good; it was a snappy airplane, so that I could move the nose from one spot to another quite nicely. The final response seemed to be a bit underdamped. I would get about 3 or 4 oscillations, although they were damped, before I could get the nose settled down right where I wanted it.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

There was a little bit of a tendency for the initial response to be too abrupt and the final response to be under damped; so pitch attitude and tracking capability were not all that good, particularly when I tried to acquire a target rapidly. I just couldn't put the nose right on a point and hold it.

NORMAL ACCELERATION CONTROL

Normal acceleration control was really good, the airplane was quite maneuverable, no problem at all, and I enjoyed the maneuvering capability. Longitudinal control in steep turns also seemed to be good. I seemed to have less of an oscillatory problem tracking under higher g than I did tracking with just one g on the airplane.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbance seemed to have very little effect on the airplane, which surprised me a little bit since the airplane seemed lightly damped. Anyway, the effect was minor, a little more effort required but no more than a minor deterioration of performance.

INSTRUMENT FLIGHT PROBLEMS

During the discrete error tracking task it was quite obvious that I was getting several oscillations before I could get the airplane to settle down. It sure took a lot longer to get settled down on the target than I would have liked. In random disturbance, it was less noticeable because it moved randomly and I coupled, so it was kind of hard to tell whether it was me or the display that was moving. I really didn't see anything that didn't show up VFR.

GOOD FEATURES

It was a quite maneuverable airplane, I could pull a lot of g with no problem.

OBJECTIONABLE FEATURES

I really objected to the 3- to 4-cycle osc llation that I would get, when tracking abruptly, before getting settled down on the target. I really wasn't too good at adding damping to the system myself; I simply waited for it to damp itself out.

PRIMARY REASON FOR PILOT RATING

I believe it was acceptable, although I found the underdamped response was at least moderately objectionable.

CONFIGURATION 4A REFUELING PILOT A PR 3 PIOR 1
EVALUATION FLT 16

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces seemed to be just a little bit light, and the airplane was a little sensitive. If I started chasing the drogue, I'd overcontrol and oscillate the airplane a little. All I had to do was stop and just think about what I was doing, and I could stop the oscillation almost completely. But the stick forces were probably a little light. Stick motion was satisfactory.

PREDICTABILITY OF RESPONSE

Predictability of airplane response to pilot inputs was certainly good. I could fly the task, I thought, with satisfactory precision.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was good. I thought I had good control capability. I could fly the airplane up to and stop right where I wanted. So, tracking of the refueling drogue was good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was no factor.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was excellent; it was no problem at all.

GOOD FEATURES

I could do the task to my satisfaction and I thought I had real good precision of control with the airplane. Not excellent, but it was good. I had to avoid chasing the drogue because I tended to oscillate the airplane in a small pitch oscillation when I chased it. But if I would just stop and think about what I was doing, I could damp the oscillation or just let it go away.

OBJECTIONABLE FEATURES

None.

PRIMARY REASON FOR PILOT RATING

I thought there was some tendency to oscillate and it was a little bit objectionable. It was no problem, certainly minimum pilot compensation was required to get the performance that I wanted.

CONFIGURATION 4A REFUELING PILOT A PR 4.5 PIOR 2
EVALUATION FLT 17

ABILITY TO TRIM

Trim was okay.

STICK FORCES

Stick forces were satisfactory, a little on the light side, and I think that might be part of the problem. Stick motion was satisfactory but noticeable because I found myself having to make numerous inputs.

PREDICTABILITY OF RESPONSE

Initial response was pretty good. The final response was a little bit oscillatory and I had some problem in keeping from bobbling the airplane.

CONFIGURATION 4A
EVALUATION FLT 17 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was only fair with a tendency to bobble the airplane. I thought the tracking capability, for the drogue at least, was only fair.

NORMAL ACCELERATION CONTROL

Normal acceleration seemed to be okay.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was okay. We did tasks in the turn, and I could get it hooked up, but it still bobbled.

GOOD FEATURES

It certainly could do the job. I could get hooked up, but not as comfortably as I would have liked.

OBJECTIONABLE FEATURES

Primarily the tendency to bobble the airplane, to overshoot my mark. I really had to discipline myself to fly on the tanker and up the hose and then into the drogue. When I tried to find the drogue, I noticeably oscillated the nose of the airplane.

PRIMARY REASON FOR PILOT RATING

It had more than minor and annoying deficiencies, down to the point where it was moderately objectionable. But, I could do the job. There was some tendency to get undesirable motions which I wasn't very good at controlling.

CONFIGURATION 4D WITH TGT PILOT A PR 8 PIOR 4 TR D
EVALUATION FLT 2_

ABILITY TO TRIM

Ability to trim was actually pretty good. I had to remind myself that I was always trimming.

STICK FORCES

Stick forces were satisfactory. Stick motions were satisfactory, but quite noticeable because the airplane oscillated quite a bit and there tended to be one continuous PIO. When I tried to damp it, all I did was make things worse. There was no reason to reselect the gearing.

PREDICTABILITY OF RESPONSE

I think the airplane was very unpredictable to a pilot input. When I tried to do anything tightly, invariably I would get into a medium-frequency, relatively high-amplitude, pilot-induced oscillation. My inputs were really out of phase with the airplane motion most of the time.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was very poor. I just couldn't control it well enough to get any tracking out of it. So the tracking capability also was very poor. It was just not possible to do the task. If I tried to do anything tightly, or any tracking at all, I would get into a quite significant destructive PIO as far as being able to track.

CONFIGURATION 4D
EVALUATION FLT 22 (Cont.)

NORMAL ACCELERATION CONTROL

Normal acceleration control was very poor because of the continuous pilot-induced oscillations.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence did make things considerably worse and when I tried to negate the effect of turbulence, I really found that it exaggerated the PIO and made it of much larger amplitude.

GOOD FEATURES

I could fly the airplane, I could maneuver it.

OBJECTIONABLE FEATURES

It was just impossible to track anything with this airplane. Anytime I tried to do any tight tracking, I would get into quite large amplitude, medium-frequency, pilot-induced oscillations. However, I could stop these by stopping whatever I was doing.

PRIMARY REASON FOR PILOT RATING

The airplane was certainly not acceptable. I think in the context of the mission some compensation was required for control. There was considerable degradation in turbulence, a moderate deterioration. Oscillations occurred anytime I attempted tight control. I had to either reduce my gain or abandon the task to recover.

CONFIGURATION 4D WITHOUT TGT PILOT A PR 9 PIOR 5 TR D
EVALUATION FLT 30

ABILITY TO TRIM

Ability to trim was good, no problems.

STICK FORCES

Stick forces were okay, nice and light. Stick motions were a bit of a problem because the airplane was very PIO prone anytime I tried to do anything of a tight tracking nature. As a matter of fact, it was almost impossible to fly a tight tracking task without getting into divergent oscillations.

PREDICTABILITY OF RESPONSE

The airplane initial response was delayed noticeably; I could see that. Final response was quite oscillatory, and if I tried to put the airplane right on a spot, it continued to oscillate. Also, if I relaxed what I was doing, the airplane would damp itself out, so the airplane did have inherent damping.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability were practically nil. Anytime I tried to do anything with the airplane, I would get a noticeable pilot-induced oscillation, and if I tried to do something tightly, it would go divergent.

NORMAL ACCELERATION CONTROL

Normal acceleration control for gross maneuvering was really not too bad. I could control it with no tendency to over g the airplane. It was only when I tried to do any tight tracking that I would get into serious oscillatory problems. I could fly the airplane through steep turns and as long as I didn't try to do any tight tracking with it, it was okay. When I did try to make small minor corrections it was noticeably PIO prone or noticeably divergent PIO-wise depending on how tightly I wished to control the airplane.

CONFIGURATION 4D
EVALUATION FLT 30 (Cont.)

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances didn't really affect the airplane attitude very much;however, they kept the airplane moving quite a bit. The big problem was that when I tried to counter the random disturbances, the airplane would get into a PIO, so the ultimate effect of the random disturbances was pretty bad. I would certainly say in the best efforts required category with at least a moderate deterioration in my performance.

INSTRUMENT FLIGHT PROBLEMS

I just could not do either of the two IFR tracking tasks. All I could do was pull and then stop what I was doing, let the airplane damp itself out and hope that the horizontal bar was somewhere near center. So the discrete tracking was PIO-prone unless I made a conscious effort to stop making inputs. The random disturbance one was a continuous PIO because it obviously required continuous inputs.

GOOD FEATURES

I could maneuver the airplane, could fly it, and I didn't feel that I was going to over g the airplane, but that was about the only good feature.

OBJECTIONABLE FEATURES

The major, and serious, objection was the PIO tendency of the airplane. The tighter I tried to fly the airplane, the more divergent the oscillations became. In general it was a very poor airplane with no tracking capability at all. When trying to do the tight tracking task, controllability may be a problem. All I could really do was, once the airplane started oscillating, just stop what I was doing and let the natural damping of the airplane stop it.

PRIMARY REASON FOR PILOT RATING

It certainly was not acceptable for the mission. I think it was down to the point where retaining control was a real problem.

CONFIGURATION 4D REFUELING PILOT A PR 4 PIOR 2
EVALUATION FLT 18

ABILITY TO TRIM

Trim wasn't very good. I never did really get it trimmed. I'm not sure if it was because I was looking at the tanker, at the nose climbing a little bit, giving me a different reference.

STICK FORCES

Stick forces were initially very light, and I changed the gearing to make them heavier and more acceptable. Stick motion was satisfactory. It was very small, barely noticeable.

PREDICTABILITY OF RESPONSE

The initial response seemed to be pretty good but the final response was a little bit oscillatory. I did have the capability of damping it out.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was fair; certainly not as precise as some that I've seen. I didn't have nice fine control, and I'm not sure whether it was because I was modifying my technique to get real light grip on the stick or whether it was something else. I didn't feel very comfortable with it. Tracking capability was in that same category.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not looked at.

CONFIGURATION 4D
EVALUATION FLT 18 (Cont.)

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was poor. It seemed to be better in close than when I was way out where I set up a one- or two-cycle oscillation. I may have been 10 or so feet from the drogue when I would get longitudinal oscillations so it just wasn't very good.

GOOD FEATURES

It certainly could do the job.

OBJECTIONABLE FEATURES

Not as precise as I would have liked it to be. The tendency to bobble the airplane a little bit before getting to the drogue. The pilot does have to impart damping into the system. I really didn't feel comfortable with it, primarily because of the tendency to bobble the airplane farther out. There was some undesirable motion that I could eliminate by imparting damping into the system.

CONFIGURATION 5A WITH TGT PILOT A PR 6 PIOR 3.5 TR E
EVALUATION FLT 24

ABILITY TO TRIM

The ability to trim was good. No problem with establishing a trim position.

STICK FORCES

Stick forces and motions were satisfactory, no real problems.

PREDICTABILITY OF RESPONSE

The initial response was quite snappy and the final response was a bit oscillatory. The final response was, I thought, the cause of most of my problems.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was only fair. I had to impart a lot of damping to the total system and I noticed myself moving the stick quite a bit. The nose tended to oscillate quite a bit during the tracking. The tracking itself was very poor, although I am willing to admit that one might get several shots into the target. The nose of the airplane moved around considerably during the tracking run and it looked a little like a pilot-induced oscillation. I'm really not sure that was the case. I just wasn't very good at damping out the oscillations, but it was not something that seemed to progress in a classical PIO form where the pilot seems to feed the oscillations. The tracking was poor; I would say marginally acceptable.

NORMAL ACCELERATION CONTROL

Normal acceleration control was really not too bad; I could pull g and maneuver the airplane quite well. During turns it was okay holding steady g, when I had it established, but invariably I would oscillate the airplane getting a steady g established.

EFFECTS OF RANDOM DISTURBANCE INPUTS

The turbulence really had an effect on the airplane; moved it around quite dramatically and I seemed to make things worse when I tried to counter the turbulence. I thought it was in the best efforts required category, with at least a moderate deterioration.

GOOD FEATURES

I could certainly maneuver the airplane, pull a lot of g. That was probably its best feature.

CONFIGURATION 5A
EVALUATION FLT 24 (Cont.)

OBJECTIONABLE FEATURES

The tracking was very poor; however, I thought it was a case where I might get a shot off. The pilot has to impart damping to the system, which I wasn't very good at. The big objection was the turbulence response.

PRIMARY REASON FOR PILOT RATING

I thought that it was marginally acceptable.

CONFIGURATION 5A   REFUELING   PILOT A   PR 4   PIOR 2
EVALUATION FLT 17

STICK FORCES

Stick forces were satisfactory, but light. In close there was a tendency for me to bobble the airplane a little.

PREDICTABILITY OF RESPONSE

Predictability of the airplane's initial response was very good. The airplane was snappy and I had really fine control of the initial response. The final response was lightly damped but I could damp the system easily enough.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during refueling was interesting in that about 10 or 15 feet out from the drogue, I would almost consistently go through a little oscillation. But when I got up close to the basket, I had really fine attitude control; I was able to put the probe in the basket reasonably well. So the tracking capability was probably okay as far as tracking a drogue.

NORMAL ACCELERATION CONTROL

Normal acceleration control was no problem.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control was good, except for the tendency to oscillate; longitudinal control in turns, even hooked-up, was no problem.

GOOD FEATURES

I liked the fine attitude control up close to the drogue.

OBJECTIONABLE FEATURES

The tendency for the airplane to be lightly damped was objectionable, but it only seemed to affect my hook-up capability when I was a little out from the drogue. It was sufficient that it would make it disagreeable for you. I thought that should be fixed. I had to use very, very small inputs to the stick. I did have to impart damping into the system.

PRIMARY REASON FOR PILOT RATING

The tendency to oscillate 10 or so feet out behind the drogue was not much more than annoying. I did have to work at it a little bit. I did get some undesirable motion when a short distance out, but once I got up close and did the very fine minor adjustments, it didn't seem to be a problem.

CONFIGURATION 5A   REFUELING   PILOT A   PR 6   PIOR 2
EVALUATION FLT 18

ABILITY TO TRIM

Trim was okay.

CONFIGURATION 5A
EVALUATION FLT 18 (Cont.)

STICK FORCES

Stick forces were satisfactory, a little bit light for the initial response and a little heavy maybe for the final response, but okay. Stick motion was satisfactory but the thing I did notice was that I really had to discipline myself to make small inputs, or I would get the nose oscillating a fair amount. This happend when I got in close; I just had to concentrate on making small inputs.

PREDICTABILITY OF RESPONSE

Initially, the response came on a little fast, and the final response was quite oscillatory. Interestingly enough, I did get some oscillations that made it to the basket but the worst part of it was 10 or 15 feet back from the basket.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was really poor, particularly at a short distance out, and then as I got up close to the basket I still didn't have very good precision. I oscillated the probe into the basket quite a few times, and I missed a couple of times. Tracking capability followed that of the pitch attitude control.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not checked.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was only fair. There was a tendency to just sit there with a fairly high frequency oscillation going, but it really didn't change the altitude very much so I guess it was really not very bad, but it wasn't really good either. I did notice, however, that once I would get hooked up, I really had to damp the airplane to keep it from oscillating while it was connected to the other airplane.

GOOD FEATURES

I guess the only good feature was that I could do the job.

OBJECTIONABLE FEATURES

The tendency to set up medium-amplitude oscillations 10 or 15 feet behind the drogue. As I got into the drogue, I was almost always bobbling as I got hooked up; then when I tried to hold formation with the tanker, I tended to bobble the airplane some more. I really had to be light on the controls just before hook-up and afterward, while hooked-up, so that I didn't get the oscillation excited.

PRIMARY REASON FOR PILOT RATING

I think the airplane was acceptable for the job but I felt it was very objectionable and it required excessive pilot compensation. PIO was really not a good description for the oscillatory tendency because it was mostly just getting the airplane excited, but then I could damp it and not augment the oscillation.

CONFIGURATION 5A REFUELING PILOT A PR 5 PIOR 2
EVALUATION FLT 19

ABILITY TO TRIM

The ability to trim was fair to good. The airplane was a little oscillatory on its own, and that created some problems but nothing really serious as far as the trim was concerned.

STICK FORCES

Stick forces and motions were satisfactory. I didn't see any need to reselect any gearings at all.

CONFIGURATION 5A
EVALUATION FLT 19 (Cont.)

PREDICTABILITY OF RESPONSE

The initial response was relatively snappy and the final response was a bit oscillatory. I would get several oscillations when I was trying to do something precisely with the nose and I wasn't very good at getting the airplane hooked up with the precision that I would have liked.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was, at best, fair. I never had really nice, fine control so that I felt I could put the probe or nose right where I wanted. So tracking capability on the drogue itself was fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was a bit oscillatory, but fair enough.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude relative to the tanker was good, but there was a tendency for me to get several oscillations before getting up to the drogue, and that created some problems. Then there was the tendency to oscillate as I was hooking up and even after I had hooked up with the tanker. I flew one turn behind the tanker not hooked up and it seemed to be okay in a steady turn.

GOOD FEATURES

I was not really very good at it but I could do the task.

OBJECTIONABLE FEATURES

Primarily the oscillatory tendencies of the airplane, which were not pilot-induced oscillations so much, but looked like just natural airplane oscillations. I really had to impart damping to the system and I wasn't very good at that. It oscillated prior to, during, and after the hook-up.

PRIMARY REASON FOR PILOT RATING

I thought it was moderately objectionable and needed to be fixed. Therefore it wasn't considered satisfactory, but I could do the task. Undesirable motions did occur, and I could prevent them a little bit by pilot technique, but I really had to work at it.

CONFIGURATION 5D   REFUELING   PILOT A   PR 8   PIOR 4   TR NONE GIVEN
EVALUATION FLT 18

ABILITY TO TRIM

Ability to trim was okay.

STICK FORCES

Stick forces were light, but acceptable, and the stick motion was satisfactory. I cut the gearing in half and that didn't seem to help very much so I went back to the original gearing.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response to pilot inputs was just ridiculous. It was a continuous PIO anytime I tried to do anything up near the drogue or even just fly the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was just impossible; no way I was ever going to accomplish the task. Tracking capability was just ridiculously bad.

NORMAL ACCELERATION CONTROL

I couldn't control it; it was just a continuous oscillation.

CONFIGURATION 5D
EVALUATION FLT 18 (Cont.)

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was poor. There was just no way that I was going to stay anywhere near where I wanted to be.

GOOD FEATURES

I didn't feel like I was going to lose control of it and the oscillations were not really divergent although they were certainly zero damped.

OBJECTIONABLE FEATURES

The big objection of course was the inability to do the job because of the quite large oscillations that result anytime I tried to do any tight tracking task. I just had to stop whatever I was doing and let it damp itself out.

PRIMARY REASON FOR PILOT RATING

I certainly had to stop what I was doing in order to maintain control. I really had to pay attention to what I was doing, or I think it would have gone divergent and I would have to back off. I really couldn't perform the task very tightly. I didn't think it was one of those things where you would get divergent oscillations, but certainly down to where control is of concern. I did get near zero-damped oscillations and I had to abandon the task or reduce the gain in order to recover the airplane.

CONFIGURATION 5E WITH TGT PILOT A PR 8 PIOR 4 TR C
EVALUATION FLT 21

ABILITY TO TRIM

Ability to trim wasn't too bad.

STICK FORCES

Stick forces were satisfactory. Stick motions were satisfactory; however, they were quite noticeable. There was continuous stick pumping anytime I tried to track the airplane because I was in a PIO the whole time.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response to pilot inputs was very poor. Initial response was a little bit slow and then it would take off. When I tried to do anything in a tight tracking maneuver, it would just continue to oscillate at about a zero-damped, medium frequency. I would say that the airplane response was very unpredictable and, as a matter of fact, I didn't have much control over it.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was extremely poor. It was just impossible during air combat maneuvers to track the other airplane. So the tracking capability was nil.

NORMAL ACCELERATION CONTROL

Normal acceleration control, surprisingly enough, was not too bad. For gross maneuvering I could pull g and even though the airplane was a bit oscillatory, it really didn't make me feel that I was going to over g the airplane. Once again, there was a continuous pilot-induced oscillation. In turns it was the same thing. Anytime I tried to do anything a little abrupt or a little bit tight with the airplane, it would get into medium-frequency, zero-damped, pilot-induced oscillations.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence made things worse, but not too much worse because it was already pretty bad. It was enough, though, to cause me to say that there was at least some more effort required with a moderate deterioration in task performance.

CONFIGURATION 5E
EVALUATION FLT 21 (Cont.)

GOOD FEATURES

I could pull g with the airplane. I could maneuver it around even though it was only fair.

OBJECTIONABLE FEATURES

Anytime I tried to do a tight tracking task, I would get into a continuous pilot-induced oscillation. I could find no way that allowed me to stop the oscillation except to back off and release the stick.

PRIMARY REASON FOR PILOT RATING

The airplane was unacceptable; it was down to the point where I was worried about compensation for control.

CONFIGURATION 5E WITHOUT TGT PILOT A PR 9 PIOR 4.5 TR D
EVALUATION FLT 27

ABILITY TO TRIM

I thought ability to trim was quite good. I could trim it up very nicely with no problem.

STICK FORCES

Stick forces in general were quite heavy to me. But I didn't think that I wanted much lighter force, because there was a real tendency toward a PIO that was a little bit divergent when I really attempted to track aggressively and tightly. So stick forces were heavy, but I thought they were okay. Stick motions were quite noticeable because I really found myself pumping the stick to try to damp the airplane, and that turned out to be the worse thing I could do. What I finally ended up doing was to get the airplane pretty much at the attitude I wanted, then kind of relaxed on the stick and let the airplane damp out to see where the attitude was going to be. Of course that was not a very practical way to track something, but at least it cut down on the oscillations. So there was quite a bit of stick motion involved but primarily because I was pumping the stick. No real second thoughts, however, on gear selection.

PREDICTABILITY OF RESPONSE

The airplane response was quite unpredictable. It was very sluggish initially as I made an input, and then it was almost as if I could count a thousand one, a thousand two, before the airplane began to respond. The tendency then was to dig in so that, in general, the predictability of the airplane response, either the initial or final response, was very poor.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

My ability to control pitch attitude while tracking was very poor, very limited and in general quite unacceptable. When I did try to track closely I would say that the oscillations were getting to the point where they were approaching being divergent.

NORMAL ACCELERATION CONTROL

Normal acceleration control as far as trying to pull a given g and trying to hold it was poor; however, I could maneuver the airplane and once I got it in a steady-state maneuver, it didn't ever feel like I was going to pull more g than I wanted in a gross maneuver. However, in tracking, some of the oscillations I got were quite large. In the tracking, the control of normal acceleration was poor; just for general maneuvering,when I wasn't trying to do something tightly, it was okay. In steep turns, I didn't have real fine control of the longitudinal but I could sure make steep turns and maneuver the airplane as long as I wasn't trying to do things precisely.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances moved the airplane quite a bit; therefore, when I tried to track in the presence of random disturbances, it compounded the problems and made it even worse.

CONFIGURATION 5E
EVALUATION FLT 27 (Cont.)

INSTRUMENT FLIGHT PROBLEMS

Looking at both the tracking maneuvers head down (IFR) in the cockpit, I wasn't very good with either one of them. As a matter of fact, I had to force myself to lower my gain and use a technique that I described earlier where you have to make an input, wait, and see where it settles down, hoping that you are somewhere near the needle. This was completely unacceptable.

GOOD FEATURES

I guess there weren't any good features. I could maneuver the airplane throughout gross maneuvers reasonably comfortably.

OBJECTIONABLE FEATURES

There was quite a strong tendency toward pilot-induced oscillations and the like when trying to do anything of a tight tracking nature. So, in general, I thought the airplane was quite unacceptable for the fighter mission and getting down to the point where controllability was certainly a problem.

PRIMARY REASON FOR PILOT RATING

The airplane was controllable, but, when I did tight tracking I really had to worry about the controllability of the airplane. I really thought it was bad. The oscillations when I tried to do real tight tracking were approaching the point of being divergent, but it wasn't something that would get away from you.

CONFIGURATION 5E   REFUELING   PILOT A   PR 9   PIOR 5   TR NONE GIVEN
EVALUATION FLT 19

ABILITY TO TRIM

I really can't comment on the ability to trim; I didn't.

STICK FORCES

Stick forces were satisfactory. The stick motions were quite noticeable because of the large tendency to PIO, and it was quite obvious that I was causing the PIO.

PREDICTABILITY OF RESPONSE

The airplane response was quite unpredictable; initial response was slow and in the final response, I had a large tendency to overcontrol the airplane. It was just a matter of luck as to whether I was going to end up where I wanted.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was very poor, completely unacceptable. The closer I got to the drogue the larger the amplitude of the PIO's became. So the capability of tracking the drogue was very poor.

NORMAL ACCELERATION CONTROL

Normal acceleration control was poor.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was very poor. As I got closer to the drogue I got quite large amplitude oscillations, there was no way I was going to get near the drogue.

GOOD FEATURES

I could fly the airplane. I really didn't think it was going to be too bad when I first started out.

CONFIGURATION 5E
EVALUATION FLT 19 (Cont.)

OBJECTIONABLE FEATURES

As I got very close to the drogue, the large PIO's took over; that was the major objection.

PRIMARY REASON FOR PILOT RATING

The unpredictability of the response and the tendency toward divergent PIO's as I tightened up on the task make the airplane completely unacceptable. The only thing I could do was abandon the task and back off. I don't think you'd ever get the refueling accomplished. I think intense pilot compensation is required for control because of the divergent oscillations when attempting to do the task. You have to abandon the task or back off.

CONFIGURATION 9 WITH TGT PILOT A PR 6 PIOR 1 TR B
EVALUATION FLT 20

ABILITY TO TRIM

Ability to trim was very poor. I wasn't sure if it felt stable or not, but it was.

STICK FORCES

The initial stick forces were completely unacceptable to me for the fighter mission. I got very tired of pulling on the stick. Stick motion wasn't nearly as noticeable as the stick forces were. I lightened the stick force, and I could't see a big difference. There was more of a tendency to over g the airplane with the lighter forces, but I didn't get them light enough that it felt like I was going to break anything. So trying to get heavy enough forces to give me g protection yet light enough to maneuver the airplane was a compromise that was difficult to achieve.

PREDICTABILITY OF RESPONSE

I thought the initial response was very slow and the final response was a little bit unpredictable. Predictability of the response was very poor for both the initial and final. For the final response, once I got it pointed where I wanted, it would stay there. There was not much of a tendency for the attitude to change.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was very poor. It was much too slow to be a good, comfortable tracking airplane. Forces were heavy, and the combination of heavy forces and the slow pitch response made for a very poor flying airplane. Tracking capability was interesting; once I got it on the target, I could hold it there and I could track as long as the target airplane made a nice steady flight path. When he changed, or I got off, it took me quite a while to get it back on the target. So, the tracking capability was great as long as I didn't have to make any changes. But other than that it was very poor because it was too slow getting on the target.

NORMAL ACCELERATION CONTROL

Normal acceleration control was one of the poorer features of the airplane. I got quite a negative g when I tried to pull up and go over the top to roll in on the target. Longitudinal control in turns during ACM was only fair. It was a very heavy airplane, at least with the initial forces, and not much better with the final.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence didn't seem to move the airplane very much. It didn't really detract from the performance very much. There was a little more effort required, but no real significant deterioration.

GOOD FEATURES

I could keep it in the sky until I over g'd it, but it really wasn't very good.

CONFIGURATION 9
EVALUATION FLT 20 (Cont.)

OBJECTIONABLE FEATURES

The very heavy forces and the tendency of just not being able to get the pipper back on target were objectionable. I really had to stay ahead of the airplane and be very smooth, because once off the target, it was difficult to get back on.

PRIMARY REASON FOR PILOT RATING

I don't really think I would buy this for the fighter mission. I could track the target a little bit; it just took a long time to get on target. I didn't like the forces or the g capability. I thought I could do the job, but I found the airplane to be very objectionable. It was tolerable. I could do it, but not very well; I could track him I would have to admit. There was really no undesirable motion; I just couldn't make the airplane move very abruptly.

CONFIGURATION 9 REFUELING PILOT A PR 5 PIOR 5 TR NONE GIVEN
EVALUATION FLT 16

ABILITY TO TRIM

Ability to trim was very poor.

STICK FORCES

Stick forces were satisfactory but the couple of large maneuvers that we did following the step input indicated that it was not a very good airplane. Stick motion, however, was satisfactory, very small.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response to pilot inputs was poor, but I did adapt to the airplane and got better, and by the end I was getting satisfactory. So the initial response was very slow and the final response was also slow.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

It was difficult to control pitch attitude although not impossible. In the refueling portion, when I first got up there I wasn't sure I was going to make it, but as I adapted to the airplane I was doing much better. Tracking capability during the in-flight refueling was only fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was poor.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was fair. I did stay hooked up in part of a turn and I did set up a slight oscillation, but I got it damped out.

GOOD FEATURES

I would have to say it was acceptable; I could do the task.

OBJECTIONABLE FEATURES

With the tendency to overcontrol and the very slow response, I really had to go gingerly on the controls to keep the airplane from getting away from me. If I tightened up on the controls I would get a PIO.

PRIMARY REASON FOR PILOT RATING

I thought it was mildly objectionable, but I thought it was adequate. I did get undesirable motions when I attempted tight control.

CONFIGURATION 9 REFUELING PILOT A PR 6 PIOR 2 TR NONE GIVEN
EVALUATION FLT 18

ABILITY TO TRIM

The ability to trim was very poor. I had a lot of difficulty just getting the airplane to stay in level flight.

STICK FORCES

Stick forces were pretty wild. I pulled up to roll to another target and almost went to negative g as I tried to roll over. So normal acceleration control just from that was unsatisfactory, even unacceptable. Stick forces were okay for very small amplitude maneuvering. Stick motion was satisfactory, but it was really a slow motion airplane. I would find myself having to make a little input and just discipline myself to wait for something to happen and not do anything abruptly. So the fact that I had to really discipline my inputs was noticeable.

PREDICTABILITY OF RESPONSE

The airplane response was quite unpredictable. The initial response was very slow, but there was a tendency to take off in the final response. I had to make real small, close-type inputs and just wait for things to happen.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during refueling was very poor. I did get it hooked up. I could do the mission, but I never got very good at it. I did not adapt to the airplane very well. The tracking capability for in-flight refueling was poor.

NORMAL ACCELERATION CONTROL

Normal acceleration control was completely unacceptable.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

I really had to stay on top of it and make sure that I didn't make a very large input. I made one turn when not hooked up, and that was very poor.

GOOD FEATURES

Really none. I could get it hooked up to the tanker but I really had to discipline myself not to do anything at all very rapidly.

OBJECTIONABLE FEATURES

A very slow response and the strong tendency to overcontrol was very objectionable. The discipline required to keep myself from making a large input really was very poor. I had to put in a little pulse and hold it and wait to see what was going to happen.

PRIMARY REASON FOR PILOT RATING

I found it very objectionable for the refueling task itself. I think I could do the job, but I think it certainly required extensive pilot compensation. The airplane was slow responding and wanted to take off on me; that was the problem, not any oscillatory pilot-induced type oscillations.

CONFIGURATION 9 REFUELING PILOT A PR 5 PIOR 2 TR NONE GIVEN
EVALUATION FLT 19

ABILITY TO TRIM

Ability to trim was poor.

STICK FORCES

Stick forces and motions were satisfactory.

CONFIGURATION 9
EVALUATION FLT 19 (Cont.)

PREDICTABILITY OF RESPONSE

Predictability of airplane response to pilot inputs was only fair. There was a very slow initial response and a tendency to oscillate going into the drogue.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was only fair, with a tendency to oscillate before and just after hook-up. The tracking capability was only fair.

NORMAL ACCELERATION CONTROL

Normal acceleration control was poor.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was good.

GOOD FEATURES

I could do the job but there was nothing really very good about it.

OBJECTIONABLE FEATURES

The tendency to oscillate was objectionable. It was hard to get a hook-up, I really had to be ginger on the controls and do nothing abruptly.

PRIMARY REASON FOR PILOT RATING

It was moderately objectionable. Undesirable motions were there when I tried abrupt maneuvers.

CONFIGURATION 10 WITH TGT PILOT A PR 3 PIOR 1 TR B
EVALUATION FLT 21

ABILITY TO TRIM

Ability to trim was poor. I think I've seen some that were worse, but in general the trimability was poor.

STICK FORCES

Stick forces and motions were quite satisfactory. I didn't see any reason to reselect the gear ratio.

PREDICTABILITY OF RESPONSE

The predictability of the airplane response was good. I noticed that it was a little slow initially but I had real fine control, and keeping the pipper on the target didn't seem to be too difficult. This was a little bit of a slow motion airplane, but okay.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the ACM was good. I was able to track the target reasonably well. The tracking was not excellent, but it was good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was good. We did some fairly significant maneuvering, and I was able to keep up with the other airplane quite nicely.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence seemed to have very little effect, which was a good feature.

GOOD FEATURES

I thought the tracking was good.

OBJECTIONABLE FEATURES

Minor objection to the slow initial response and a bit of a tendency to overcontrol. In general, it was a well damped airplane with which I was able to track reasonably well.

PRIMARY REASON FOR PILOT RATING

I thought it was acceptable; some of the deficiencies I found were mildly unpleasant.

CONFIGURATION 10 REFUELING PILOT A PR 6 PIOR 3
EVALUATION FLT 17

ABILITY TO TRIM

Ability to trim was fair to poor.

STICK FORCES

Stick forces and motions were satisfactory; they weren't a problem.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response was poor. I didn't have real fine initial control. Initial response was quite slow; consequently, stopping the airplane once I got it started seemed to be difficult. The general response characteristics of the airplane were poor.

CONFIGURATION 10
EVALUATION FLT 17 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was poor. I could do the job, but I really worked hard. Tracking capability was poor.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not really tested.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was good. The kinds of motions I was talking about were small enough so that I never felt as if I didn't want to hook the airplane up, but I wasn't very good at it. Longitudinal control during the refueling was poor; I did some hook-ups in a turn and I had considerable difficulty.

GOOD FEATURES

I thought I could do the job; I could get it hooked up.

OBJECTIONABLE FEATURES

Just poor performance. I got up to the drogue, but I didn't always make a hook-up. I never could get the nice, fine corrections needed for good refueling hook-ups. There really was no technique that allowed me to do the job as well as I wanted.

PRIMARY REASON FOR PILOT RATING

I really think you could do the job but it takes a lot of pilot compensation; I really worked on that evaluation. I was having trouble controlling the airplane. I was getting motions that I didn't like and I really had to sacrifice task performance but I couldn't stop them very well either.

CONFIGURATION 10 REFUELING PILOT A PR 4 PIOR 1.5
EVALUATION FLT 19

ABILITY TO TRIM

Ability to trim was fair to good.

STICK FORCES

Stick forces were satisfactory, and the motions were satisfactory, but noticeable. It was a confusing airplane because sometimes I could do a real good job, and at other times I didn't seem to do so well; I couldn't really understand why.

PREDICTABILITY OF RESPONSE

The airplane response seemed to be a little bit slow initially. Sometimes I would get up to the drogue, and I just didn't feel that I had the airplane under as fine a control as I would like. I'd often get a one-cycle oscillation into the drogue.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was certainly good. I could fly it up, and sometimes I'd hold the probe in the basket, and then complete the hook-up. At other times I didn't seem to be able to do that. I would say tracking capability was fair to good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was not as good as I would have liked.

CONFIGURATION 10
EVALUATION FLT 19 (Cont.)

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was good.

GOOD FEATURES

I certainly could do the job; an acceptable airplane.

OBJECTIONABLE FEATURES

Just not as fine control as I would have liked, but that was a minor objection. I just couldn't quite hack the precision there at the end as well as I would have liked. I had to be a little bit careful, when I got it near the basket, not to make an abrupt change because it would move faster than I would want. I'm going to call these minor but annoying deficiencies. There was some tendency to introduce undesirable motions, particularly if I did something abruptly.

CONFIGURATION 11   WITH TGT   PILOT A   PR 2.5   PIOR 1   TR B
EVALUATION FLT 4

ABILITY TO TRIM

I didn't think the ability to trim was very good. I had some difficulty getting the airplane trimmed.

STICK FORCES

I thought the stick forces were a little heavier than I wanted at first, but as I flew the airplane and adapted to them, I didn't think they were too bad. So the forces were satisfactory. Stick motion was not noticeable; I thought it was quite satisfactory. I probably should have looked at a little lighter force just for my own identification, but I didn't. I am willing to say that what we had was satisfactory.

PREDICTABILITY OF RESPONSE

I thought the airplane predictability to pilot response was very good; I was reasonably impressed with my ability to track.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

The pitch attitude control was very good. Tracking capability I thought was excellent.

NORMAL ACCELERATION CONTROL

Normal acceleration control also seemed to be quite good. Longitudinal control in the turns was really quite good. I found that my tracking capability was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence didn't seem to have very much influence on the airplane either. As a matter of fact, I could counter the turbulence inputs and maintain a fair degree of tracking capability.

GOOD FEATURES

I thought the tracking capability and the acceleration control of the airplane were quite good. In general, it was a very comfortable airplane to fly. As a matter of fact, I flew it reasonably aggressively and enjoyed it.

OBJECTIONABLE FEATURES

One very minor objection was that the stick forces were a little heavy, but compatible with the airplane.

PRIMARY REASON FOR PILOT RATING

It was satisfactory. There was definitely no tendency to induce PIO's or undesirable motions. There was no significant deterioration of my performance in the presence of random disturbances.

CONFIGURATION 11   WITHOUT TGT   PILOT A   PR 4.5   PIOR 1   TR B
EVALUATION FLT 30

ABILITY TO TRIM

Ability to trim was poor. There was not a very well defined trim position.

STICK FORCES

Stick forces were heavy. It did seem to provide noticeable g protection in that I didn't over g the airplane even though I had a very slight tendency to dig in a little bit. Stick motions were noticeable, I guess because of the heavier forces, but they were still okay.

PREDICTABILITY OF RESPONSE

The initial response was a bit slow and it took a quite noticeable, large input to get the airplane to respond as fast as I wanted. In general, I didn't like the speed of the response initially. Final response, however, seemed to be well damped. There was a tendency to overshoot the target maybe just once and then stop there, but it worked out pretty good.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability were fair. It was a well damped airplane with no tendency to move around once it was settled down on the target. The biggest complaint I had was the slow initial response and the inability to get it on a target.

NORMAL ACCELERATION CONTROL

Normal acceleration control was likewise fair; too slow coming on and it took a lot of force to hold it there but my control of it seemed to be pretty good. No problem in steep turns; I could make steep turns and hold the g with no real difficulty.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbance didn't seem to have much of an effect on the airplane; it was barely noticeable. Perhaps in the "more effort required" category, but no deterioration of my performance.

INSTRUMENT FLIGHT PROBLEMS

On the two tracking tasks (IFR), I noticed the same things that I had seen before. On the discrete tracking it was just slow in getting up to the point I wanted, and there was a tendency to overshoot it maybe one time and then settle down. On the random tracking, I was almost always behind because of the slowness of the initial response.

GOOD FEATURES

The airplane was maneuverable. I didn't feel that I was going to over g, although there was a slight tendency to dig in. Tracking was fair.

OBJECTIONABLE FEATURES

The slow initial response was objectionable. I liked the fact that the airplane was well damped and once it got to where I wanted, it would stop with one overshoot and stay on the target. I also objected to the heavy stick forces. It took quite large inputs to get the airplane to move rapidly initially, and then I had to ease out or check forward to maintain my positive g.

PRIMARY REASON FOR PILOT RATING

I think what I saw was acceptable. It had a little more than a minor deficiency. You can do the job, you can track, but it is a very slow airplane.

CONFIGURATION 11   REFUELING   PILOT A   PR 2.5   PIOR 1
EVALUATION FLT 17

ABILITY TO TRIM

Ability to trim was fair.

STICK FORCES

Stick forces and motion were good.

PREDICTABILITY OF RESPONSE

The initial response was a little bit slow coming on, but I was surprisingly good with the airplane. This was a very solid airplane, hardly moved around the sky, but the initial response was a little slower than I would have liked.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the refueling was quite good. Not as snappy as I would have liked, but acceptable and satisfactory. Tracking capability was good; no problem with that.

ALTITUDE CONTROL RELATIVE TO TANKER AIRCRAFT

Altitude control relative to the tanker was good.

GOOD FEATURES

It was really a solid-feeling airplane I think. I could get it hooked up quite nicely.

OBJECTIONABLE FEATURES

The initial response was slow and I couldn't get that nice, fine control I wanted.

PRIMARY REASON FOR PILOT RATING

You could do a good job with the airplane. It was satisfactory; there was no problem. I needed a little finer control. There was no tendency to set up pilot-induced oscillations.

CONFIGURATION 6B   WITH TGT   PILOT A   PR 5   PIOR 2   TR C
EVALUATION FLT 2

ABILITY TO TRIM

I didn't see any problems with trimming the airplane; I thought it was certainly okay.

STICK FORCES

Stick forces were just about what I thought I would like as far as comfort for pulling g, but may have contributed to the tendency I had to overcontrol the g. Anyway I thought the forces were quite satisfactory for the air-to-air task. Stick motion was satisfactory. I didn't even feel that I was moving the stick and I liked that. For small, continuous tracking corrections, the forces were just about right.

PREDICTABILITY OF RESPONSE

Response of the airplane to pilot inputs was quite nice for small inputs. But when I tried to maneuver the airplane grossly, the g built up much faster than I expected, and I found myself having to stop the g build-up by either easing off or moving the stick forward. A couple times I inadvertently disengaged the system when I didn't mean to because I was watching the g and the g just actually built up when I didn't think it was going to.

CONFIGURATION 6B
EVALUATION FLT 2 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

The attitude control, in general, was not really poor, but not good either in that I had a strong tendency to overcontrol. It was particularly noticeable when I tried to make a rapid or abrupt maneuver following the other airplane. The tracking capability, however, was relatively good. Once I was following and tracking steadily, making small corrections wasn't all that much of a problem.

NORMAL ACCELERATION CONTROL

Normal acceleration control was the biggest problem. Maneuvering the airplane abruptly, I would overcontrol. There was a tendency to over g the airplane. The longitudinal control in turns, once I had a steady g on the airplane, making small corrections about it was no problem. The biggest problem was achieving a steady g.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence didn't really seem to be a major factor; it reduced my tracking capabilities somewhat. It was more noticeable lateral-directionally than it was in the longitudinal mode, but it did make the task more difficult. Lateral-directional control was satisfactory.

GOOD FEATURES

I liked the way the airplane tracked, and the light stick forces I had in steady maneuvers.

OBJECTIONABLE FEATURES

The major objection, it made the airplane unsatisfactory, was the tendency to overcontrol the airplane in g during abrupt manuevers. I had to be careful anytime I wanted to do anything abruptly. I would find myself sitting there with a lot more g than I anticipated.

PRIMARY REASON FOR PILOT RATING

I thought the airplane was acceptable. It seemed to be a good tracking airplane; however, I found the tendency to overcontrol in g certainly moderately objectionable. I found myself using more pilot compensation in keeping the g where I wanted it than I would have liked. I think you need to be able to maneuver the airplane to its full capability without feeling that you are going to overstress it. I didn't feel as if there was any tendency to overcontrol. I didn't think that any more effort was required in turbulence. There was, however, a deterioration in my task performance, which was certainly minor.

CONFIGURATION 6B WITH TGT PILOT B PR 7 PIOR 4 TR F
EVALUATION FLT 13

ABILITY TO TRIM

Ability to trim, no problem.

STICK FORCES

Stick forces were too high at the higher g loads.

PREDICTABILITY OF RESPONSE

In the target acquisition phase, I would put the g on and I didn't have too good an idea where the g was going to stop. I had to use a little caution not to over g, but the stick forces were high enough that I would get some kind of cue that something was happening. Up to 3 g's the forces were getting pretty high and if I had to extrapolate that up to 7 g's it would be very high stick forces, if they were linear.

CONFIGURATION 6B
EVALUATION FLT 13 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during tracking was difficult because I couldn't make the pipper stop where I wanted. If I used a strong motion with the stick either forward or aft I would get a bobbling with pipper, almost a PIO'ing.

NORMAL ACCELERATION CONTROL

Normal acceleration control; high stick forces during the acquisition with no real knowledge from your stick to attitude gearing of what the pilot was going to see or when the nose was going to stop by just the stick feel. Control in turns during the tracking portion was difficult; as I said, the pipper bobbied.

EFFECTS OF RANDOM DISTURBANCE INPUTS

I would put turbulence on the tracking maneuvers, and it was impossible to track. The darn turbulence would feed into the system and the pipper would just go all over the sky. I would chase it trying to get it any where near the target, and the best I could do was just spray bullets all over the sky.

GOOD FEATURES

It wasn't the worst airplane in the world for tracking; I guess that is the best I can say.

OBJECTIONABLE FEATURES

I couldn't guarantee or predict the g load during the acquisition phase, and that might have resulted in overstressing if I went to higher g load. I couldn't make the pipper stay still on the target and there was definitely something in the system inducing this. It wasn't all pilot. I found myself pressing my arm down firmly on my leg so that I could hold the stick forces to keep from over g'ing.

PRIMARY REASON FOR PILOT RATING

I would say it was not satisfactory without improvement. There were very objectionable but tolerable deficiencies during acquisition and it required extensive pilot compensation to get the airplane to move where I wanted without over stressing it. Tracking capability was a major deficiency; I could not track. Adequate performance was not attainable with maximum pilot compensation. It certainly was controllable. I don't think I could obtain the tracking performance I wanted. In turbulence, it was still controllable, of course, but it was impossible to track with it longitudinally. It required "best efforts" with major deterioration of task performance. When I was trimmed in the g load during the abrupt tracking maneuvers I had to reduce my gain for tight control.

CONFIGURATION 6B WITHOUT TGT PILOT A PR 3 PIOR 1 TR D
EVALUATION FLT 2

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces were good and stick motions were quite compatible. No real second thoughts on what I might like for the stick forces and stick motions. It was quite a maneuverable airplane. I could pull lots of g with a very slight feeling that it was digging in a little, but it was just kind of a sensation rather than something I could see.

PREDICTABILITY OF RESPONSE

The predictability of the airplane response to pilot inputs was pretty good initially. There just seemed to be a very tiny lag but then I was able to move and stop the airplane right where I wanted, and I thought I had reasonable good control of it.

CONFIGURATION 6B
EVALUATION FLT 8 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

During the tracking task, my attitude control and tracking capability seemed to be good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was fair in that there was a slight tendency to overcontrol, but not to the extent that I had to consciously do anything about it. It was just that the airplane seemed to come on a little quicker than what I had bargained for, but not bad. Steep turns for holding g and making continual maneuvers was quite comfortable, quite good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random noise bothered me quite a bit and we went back and looked at that again. When in a steady turn and holding g, like 2 incremental or 2-1/2, the random disturbance was quite noticeable and made the airplane feel a little bit ratchety. In other words, it would kind of move along and then seemed to stop. So I think the random disturbance would affect tracking capability.

INSTRUMENT FLIGHT PROBLEMS

I didn't see any problems flying IFR that I hadn't seen VFR.

GOOD FEATURES

It was a maneuverable airplane, and I thought a reasonably good tracking airplane.

OBJECTIONABLE FEATURES

I had no major objections, but a couple of minor ones: A tendency for the airplane to give me the sensation that I was getting more g than I wanted during large maneuvers; more of a feeling than anything else. Secondly, I thought the turbulence response was objectionable.

PRIMARY REASON FOR PILOT RATING

I thought the airplane was acceptable; it was satisfactory. The turbulence response made me downgrade it a little bit. It was responsive to turbulence; more effort was required. I thought there was a moderate deterioration in performance.

CONFIGURATION 6B WITHOUT TGT PILOT B PR 6 PIOR 3 TR F
EVALUATION FLT 11

ABILITY TO TRIM

Any slight stick motion created a lot of bobbling in longitudinal g and therefore trimming was difficult because if I put a piece of trim in there, either the trim would cause a bobble in g or just moving the trim button would bobble the stick.

STICK FORCES

Stick forces seemed to be okay; I didn't have any complaints about that. There was very little stick motion or force away from trim to get a sizable increase in g.

PREDICTABLILITY OF RESPONSE

Response very difficult to predict. For normal pilot stick motions, it was difficult to predict the response I was going to get from the stick in terms of g load.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

When I got to a desired attitude or g load, it was difficult to hold. So, I say pitch attitude control was difficult.

CONFIGURATION 6B
EVALUATION FLT 11 (Cont.)

NORMAL ACCELERATION CONTROL

Normal acceleration control was difficult and was not precise. I couldn't hold a constant g load either IFR or VFR. I could bobble sometimes as much as half a g. In steep turns, it was difficult to track. Once I had stick forces established and was near the attitude I wanted, it seemed very difficult to hold it.

EFFECTS OF RANDOM DISTURBANCE INPUTS

With random noise it was even worse. A slight gust upset would trigger either my arm or the stick, creating another input to the control system, and I would get a g bobble. So it would be hard to track.

INSTRUMENT FLIGHT PROBLEMS

With the attitude indicater in the cockpit, which was relatively insensitive to small perturbations, you would have a difficult time flying IFR. I switched hands to scratch my nose and put my left hand on the stick. As a result, I bobbled the g load plus or minus a g and I felt the pickup at zero g's because I just couldn't keep control of the airplane like that.

GOOD FEATURES

I didn't see any good features to speak of.

OBJECTIONABLE FEATURES

The objectionable features were that I would not complete a tracking task; I could not maintain accurate pipper on the target with the control system as it was. I felt I would have a difficult time learning this system; especially, for example, when I changed hands and the g went plus or minus an extra g that I didn't anticipate.

PRIMARY REASON FOR PILOT RATING

It had very objectionable, but tolerable, deficiencies. I think you could track with it. You might get a degradation in tracking, but it required extensive pilot compensation. I had to pay attention to it. Turbulence required "best efforts"; deterioration of the task was major. Undesirable motions were easily induced when I initiated abrupt maneuvers or when I tried to stop a maneuver expecially under IFR conditions when trying to make small inputs to change attitude.

CONFIGURATION 6C WITH TGT PILOT A PR 8 PIOR 3 TR C
EVALUATION FLT 6

ABILITY TO TRIM

Ability to trim was very poor; it was difficult to trim. As a matter of fact, I wasn't really sure whether or not it was unstable, but it wasn't. It didn't seem to be too far from it.

STICK FORCES

Stick forces were satisfactory but very nonlinear. There was a real strong tendency for the forces to lighten up as speed decreased. It wasn't unusual, when considerably off from the trim speed, to find myself having to push forward on the stick to keep the airplane from digging in. It was very uncomfortable. Stick motion was satisfactory and wasn't really noticeable. There wasn't any reason to reselect the gear ratio. The forces were okay; the problem was just the nonlinearity, probably due to the airplane itself.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response to pilot inputs was very poor. The airplane seemed to start out okay for the initial response, but the final response almost invariably overshot what I had expected or wanted to get with g.

CONFIGURATION 6C
EVALUATION FLT 6 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during ACM was poor. The airplane seemed to have a lag from my input and then I was continually overcontrolling it. I wasn't really getting a PIO. The only time I got into something like that was when I tried to maneuver abruptly. The tracking capability itself during the ACM was very poor, but not a PIO.

NORMAL ACCELERATION CONTROL

Normal acceleration control was really the deteriorating factor. Trying to pull off a target, pull up and turn back in, I invariably overcontrolled the airplane quite dramatically. Longitudinal control in turns was okay once I had the airplane settled down. However, initially establishing a given g value for a particular turn rate was very poor and quite unsatisfactory.

EFFECTS OF RANDOM DISTURBANCE INPUTS

The turbulence had quite an effect on the airplane. I got quite large disturbances of the pipper from the target with this random disturbance, although the airplane didn't respond rapidly to the turbulence.

GOOD FEATURES

There were no particular good features about the airplane.

OBJECTIONABLE FEATURES

Primarily, the quite large tendency to overcontrol in normal acceleration was really what destroyed this airplane. I really had to be careful when maneuvering abruptly so that I didn't over g the airplane.

PRIMARY REASON FOR PILOT RATING

I think the airplane did not provide adequate performance, and that you have to worry about control. I think considerable pilot compensation, at least as far as the task is concerned, was required to keep from overcontrolling the airplane in g. I got undesirable motions, but I didn't really get into a pilot-induced oscillation. I had trouble getting the airplane back on target once I was off, and from that standpoint, turbulence really required more effort, but no more than a minor deterioration in an already poor performance without the turbulence.

CONFIGURATION 6C WITH TGT PILOT A PR 7.5 PIOR 2 TR C
EVALUATION FLT 7

ABILITY TO TRIM

My ability to trim was fair.

STICK FORCES

Stick forces were satisfactory for tracking and for general maneuvering but when I maneuvered the airplane abruptly, it really took off and I found myself really having to push the stick forward to keep the airplane from over g-ing. I didn't like the tendency at all, but the stick forces had a real tendency to lighten as I maneuvered the airplane. The stick motion was satisfactory, barely noticeable, and for that reason I liked it. As far as reselecting a gear ratio is concerned, I didn't think that changing the gear ratio was going to help because it did have good tracking capability, but I did over g during maneuvering.

PREDICTABILITY OF RESPONSE

The initial response was a little slow coming on and then it would really take off. No problem other than just gross maneuvering; the tracking wasn't bad at all.

CONFIGURATION 6C
EVALUATION FLT 7 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during tracking was not really as precise as I would have liked, but it wasn't bad. It was between fair and good. I could keep the pipper on the target quite well, with no tendency to set up an oscillation or to drift, so tracking capability was fair to good, leaning toward the good.

NORMAL ACCELERATION CONTROL

The thing that was most detrimental was the normal acceleration control. There was a real tendency for the airplane to over g when performing gross type, higher g maneuvers. I had to keep checking forward with the stick to keep from getting too much g. Longitudinal control in turns was good once it was established, but establishing the g value, when shooting for a very large increment, was quite poor.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence had quite an effect on the airplane. It moved the nose away from the target quite a bit and I wasn't real swift at getting it back on.

GOOD FEATURES

I would have to say the tracking capability was a good feature. Not outstanding, but good.

OBJECTIONABLE FEATURES

The objectionable feature that I think destroyed the usefulness of this airplane for the fighter task was the quite significant tendency to over g the airplane. I really had to watch the g when doing anything abruptly, and I had to check forward to stop from overcontrolling.

PRIMARY REASON FOR PILOT RATING

The airplane was not acceptable for the mission. Adequate performance was not attainable primarily and solely because of the tendency to over g the airplane. I thought controllability was in question because I did have to stop whatever I was doing and worry about overcontrolling the airplane. There was no tendency to PIO the airplane, but I did get an undesirable motion which was the tendency to overcontrol. Turbulence was not a real dramatic effect, but it certainly required more effort and caused at least a minor deterioration in performance.

CONFIGURATION 6C WITHOUT TGT PILOT A PR 6 PIOR 2 TR C
EVALUATION FLT 30

ABILITY TO TRIM

Ability to trim was poor; the airplane didn't want to hold its trim position very well.

STICK FORCES

Stick forces were a little heavier than I would have liked, but it was pretty obvious why they were that way. The airplane had a significant tendency to dig in and it was really quite uncomfortable because the airplane seemed to be slow responding initially, then it really wanted to take off in g after that. I didn't inadvertently overcontrol, but I had to be conscious of it, and check forward quite a bit to keep it from exceeding the desired g. Stick motions were okay.

PREDICTABILITY OF RESPONSE

The initial airplane response was relatively slow. Final response was a little bit unpredictable because of the tendency to dig in or overcontrol.

CONFIGURATION 6C
EVALUATION FLT 30 (Cont.)

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability really weren't too bad. There was a slight tendency to overshoot once, but then I could settle right back on the target. I did notice, however, on the discrete tracking task, that I was quite reluctant to make the whole change in attitude very rapidly, if there was a large change of attitude command, for fear of overcontrolling the airplane.

NORMAL ACCELERATION CONTROL

Normal acceleration control was another thing that hurt the airplane. I didn't have very good final control over the steady g value that I would achieve for an input. Once I would get the g on the airplane, though, I could control it reasonable well. Initiating a steep turn was more difficult than holding it, once established.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbance didn't seem to have a major effect on the airplane. A little more effort required; I'd say a minor deterioration in performance.

INSTRUMENT FLIGHT PROBLEMS

There was quite a reluctance on my part to make large inputs for the step-like tracking task because of the tendency to over g the airplane. Random tracking was not really all that good either because of slow initial response.

GOOD FEATURES

I could fly the airplane, and track fairly well.

OBJECTIONABLE FEATURES

I didn't like the heavy forces or the quite strong tendency for the airplane to feel as if I was going to over g it. I didn't like the slow initial response; I really had to watch the g. When I made an input it took quite a large one to get the airplane to move, and when it took off it really wanted to go. Then I would have to check forward to stop it.

PRIMARY REASON FOR PILOT RATING

It was acceptable, but I found it very objectionable.

CONFIGURATION 6D WITH TGT PILOT A PR 8 PIOR 4 TR F
EVALUATION FLT 4

ABILITY TO TRIM

Ability to trim was very poor; it was completely unsatisfactory.

STICK FORCES

Stick forces were satisfactory, but I couldn't do much with the airplane at all. Anytime I tried to maneuver the airplane, grossly or tightly, I overcontrolled, particularly when tracking the other airplane. There was a quite strong tendency toward pilot-induced oscillations. Stick motion was noticeable because I ended up pumping the stick considerably but I didn't think I would like to select a different gear ratio.

PREDICTABILITY OF RESPONSE

The airplane response to a pilot input was not at all predictable, and the airplane had a real tendency to take off in the response. The response was slow getting started and then seemed to take off with a quite strong tendency for me to over g the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

In air combat maneuvering, tracking was nearly impossible. I don't think you would ever hit the target unless it was just pure luck.

CONFIGURATION 6D
EVALUATION FLT 4 (Cont.)

NORMAL ACCELERATION CONTROL

Normal acceleration control was very poor. Any capability to pull and hold a given g did not exist. I was reluctant to do anything abruptly for fear I would over g the airplane. In the air combat maneuvering, longitudinal control was completely unacceptable. I just couldn't track with the airplane.

EFFECTS OF RANDOM DISTURBANCE INPUTS

The turbulence response was really dramatic as well. It disturbed the airplane considerably, and when I tried to correct for the turbulence input, I invariably overcontrolled. So turbulence had a very degrading effect on the airplane.

GOOD FEATURES

There were no really good features about the airplane. It was certainly in the controllable category so that I could stop things; it wasn't something I couldn't control.

OBJECTIONABLE FEATURES

The real strong tendency to over g the airplane was objectionable. Also objectionable was the inability to perform any kind of tracking maneuver without setting up a pilot-induced oscillation. I had to fly it with a real low gain, otherwise I would get an undamped or zero-damped, pilot-induced oscillation.

PRIMARY REASON FOR PILOT RATING

I thought the airplane was certainly not adequate for the mission. I thought controllability was getting to be a problem because I spent a lot of time just thinking about it and having to back off on doing the mission in order to keep the airplane from over g'ing. Considerable pilot compensation was required to keep the airplane from "getting away" in the context of the mission. If I just wished to fly straight and level there was no problem. In trying to maneuver, though, it was not very good. I didn't think the PIO was in the divergent category but I certainly picked up oscillations whenever I attempted an abrupt maneuver or tight control. I had to really abandon the task. The airplane in turbulence required my best efforts. I thought turbulence detracted even more from an already poor airplane.

CONFIGURATION 6D WITHOUT TGT PILOT A PR 9 PIOR 5 TR D
EVALUATION FLT 29

ABILITY TO TRIM

Ability to trim was relatively poor. In general, it did not hold its trim very well; the trim point wasn't very well defined.

STICK FORCES

Stick forces were a little too light. I would start to maneuver and the airplane really wanted to take off in g so I really had to watch that I didn't overcontrol. I think that was more a function of the airplane than of the stick force per g itself, because there was a tendency for the forces to lighten after I made the initial input. Stick motions were okay, but they were quite noticeable because I did end up pumping the stick quite a bit.

PREDICTABILITY OF RESPONSE

The initial response was a bit sluggish and then it really wanted to take off in the final, so the final response was not very predictable.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

There was no way I was going to track with this airplane. Pitch attitude control resulted in a quite noticeable, nearly divergent pilot-induced oscillation.

CONFIGURATION 6D
EVALUATION FLT 29 (Cont.)

NORMAL ACCELERATION CONTROL

Normal acceleration control was very poor. I really had to watch that I didn't over g the airplane. Control in steep turns was likewise poor. Once I had it established, I could hold the g pretty well but when I tried to make small corrections, I tended to get into an oscillation.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random noise was quite noticeable, not so much that it moved the airplane; but when I tried to counter the disturbance motions, I got myself into oscillations that were approaching divergent.

INSTRUMENT FLIGHT PROBLEMS

On both the IFR tracking tasks, there were similar problems, a tendency to over control and set up pilot-induced oscillations. There didn't, however, seem to be as much of a tendency for the oscillations to go divergent under the IFR situation as it did when I went VFR.

GOOD FEATURES

I didn't see any good features.

OBJECTIONABLE FEATURES

The primary objection was the inability to control the normal acceleration, a tendency to feel as if I were going to over g the airplane. Another major objection was the tendency toward divergent pilot-induced oscillations when tracking. These features made the airplane totally unacceptable. If you watch what you are doing with any degree of capability, you won't lose control of the airplane but really there was a controllability problem.

CONFIGURATION 7C WITH TGT PILOT A PR 2.5 PIOR 1 TR B
EVALUATION FLT 3

ABILITY TO TRIM

Ability to trim was quite good.

STICK FORCES

When I initially took the airplane, before tracking the target, I really thought the stick forces were going to be too light, but it turned out that I enjoyed them very much. I thought they were quite satisfactory. The stick motions were okay. There was a bit of tendency for the airplane to be sensitive about the trim point, but not bad. It was a lot better in close to the target than I thought it was going to be. So I didn't see any reason to try to reselect the elevator gearing.

PREDICTABILITY OF RESPONSE

The airplane response predictability was quite good. I could pull and hold g quite well and I could track pretty well.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

There was ever so slight a tendency for the pitch attitude control to be overly sensitive. Tracking capability was good, but with a similar problem; just a bit of a tendency to be a little too sensitive, but I enjoyed the light forces for the tracking.

NORMAL ACCELERATION CONTROL

Normal acceleration control was excellent. Longitudinal control in turns during ACM was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances didn't seem to have very much effect on the airplane.

CONFIGURATION 7C
EVALUATION FLT 3 (Cont.)

GOOD FEATURES

I liked the good solid feeling of the airplane and I liked the ability to pull g as well as I could without any tendency to bobble or over control.

OBJECTIONABLE FEATURES

The only objectionable feature I noticed was a very minor one. There was a slight tendency to be a bit too sensitive about the trim position.

PRIMARY REASON FOR PILOT RATING

I thought the airplane was quite satisfactory without improvement. The only real deficiency was that bit of over-sensitivity about trim. There was no tendency to induce undesirable motions of any consequence. In turbulence there was no significant deterioration, but a little more effort was required due to turbulence.

CONFIGURATION 7F   WITH TGT   PILOT A   PR 7   PIOR 4   TR D
EVALUATION FLT 5

ABILITY TO TRIM

I thought the ability to trim was good; no problems there.

STICK FORCES

Stick forces were certainly quite satisfactory; they were nice and light, as I like them. Stick motion was satisfactory but it was noticeable that I was pumping the stick when in those PIO's. In other words, it wasn't something that the airplane was doing, it was something that I seemed to be forcing the airplane to do. I didn't, however, see any reason to reselect the gear ratio.

PREDICTABILITY TO RESPONSE

When I was just maneuvering around the sky pulling g and so forth, I thought the predictability of the response was pretty good. The g onset was comfortable and I could stop the airplane at a given acquired g quite well.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

When I got into the air combat maneuvering, however, the pitch attitude control was noticeably oscillatory. Sometimes I would get both a lateral-directional and a longitudinal oscillation and the target tended to go around in a circle on the pipper so that the attitude control in the air combat maneuvering was poor. Consequently, the tracking capability was poor, with a tendency toward pilot-induced oscillations.

NORMAL ACCELERATION CONTROL

Normal acceleration control for gross maneuvering was good and I was pleased with it. Longitudinal control in turns was good until I started tracking. In tracking, it was very poor.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence was especially noticeable and I'm not sure whether it was just the turbulence effect or my tendency to couple with the turbulence inputs. But in general, the pitch oscillations were quite a bit worse in the presence of the random disturbances.

GOOD FEATURES

The gross maneuvering capabilities of the airplane I thought were quite good.

CONFIGURATION 7F
EVALUATION FLT 5 (Cont.)

OBJECTIONABLE FEATURES

Objectionable was the quite strong tendency toward a pilot-induced oscillation in tracking. I could stop the oscillation simply by releasing the stick a bit and letting the airplane damp itself out; it did damp quite well.

PRIMARY REASON FOR PILOT RATING

I didn't think the airplane, as it was, would provide adequate performance even with the tolerable workload. Certainly the controllability was not in question. It was just the fact that every time I got in close and tried to track the target, I would get into a pilot-induced oscillation. There was no tendency to get a divergent oscillation but I did pick up an oscillation whenever I tried to track tightly. I could reduce my gain and it would go away, however. I thought the turbulence had quite an effect on the pilot-airplane combination. More effort was required with at least a moderate deterioration in task performance.

CONFIGURATION 7F WITH TGT PILOT B PR 5 PIOR 3 TR G
EVALUATION FLT 14

ABILITY TO TRIM

It was easy to trim.

STICK FORCES

Stick forces were very comfortable; more than likely too light at the higher g loads. Stick force per g was probably very light but it was comfortable from the pilot's standpoint.

PREDICTABILITY OF RESPONSE

For the target acquisition phase, I could predict where the airplane was going except that I wasn't getting any cues to stop putting the g load on it. In general it did not have the feel of a bad airplane except that everytime I tried to acquire, I would over g the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was good and tight without any turbulence. When I pulled the stick back, the nose followed the stick and it was doing just what I wanted it to do. I just kept pulling to keep the nose going where I wanted it and I disengaged the variable stability system because of the g limits. It is conceivable that I may have gone beyond the aircraft's limits if it was extrapolating out to seven g's. But from the standpoint of acquisition it sure felt nice being able to move the nose where I wanted it to move. It was fairly easy tracking and when I got the pipper near the target I could position it pretty precisely where I wanted it. In the presence of random disturbances, it was most difficult to track. The pipper walked up and down and I couldn't make sense out of it.

NORMAL ACCELERATION CONTROL

For some reason the airplane felt so good I just kept pulling it and I obtained more g than I wanted. Maybe, extrapolating that out, I would over-stress the airplane.

EFFECTS OF RANDOM DISTURBANCE INPUTS

The turbulence and disturbance produced a bobbling that was quite a bother in tracking.

GOOD FEATURES

I think you could learn this airplane and I think it has a possibility for a good tracker.

CONFIGURATION 7F
EVALUATION FLT 14 (Cont.)

OBJECTIONABLE FEATURES

Ham-fisted pilots can't keep from over g'ing it. I guess I should have learned a technique but I didn't. 'Is it satisfactory without improvement? No. It took considerable pilot compensation to keep from over g'ing the airplane. There was increased effort with turbulence, best efforts required. I don't believe I could perform very accurately with this in turbulence. I couldn't keep the pipper going with the target long enough to get a bullet off. Undesirable motions were easily induced, the over "g" tendency. I could prevent over g'ing the airplane, but I had to sacrifice the task which was bringing the nose around and sticking it on the target.

CONFIGURATION 8A WITH TGT PILOT A PR 6 PIOR 3 TR D
EVALUATION FLT 3

ABILITY TO TRIM

The ability to trim was pretty good except that it was such a sensitive airplane that every time I would set the trim button I would get a pitch oscillation or bobble. It was not really an oscillation because it seemed to be very well damped and didn't persist. The nose did bobble, but the ability to trim the airplane and have it stay where I wanted it was pretty good.

STICK FORCES

Stick forces were quite satisfactory for maneuvering; probably too light for tracking because that was my biggest problem. As I tracked, I bobbled the nose of the airplane almost continuously anytime I made a small input. Stick motion was quite small, barely noticeable. I didn't see any reason to reselect the gearing. I liked the maneuvering capability of the airplane although I thought the tracking portion was quite poor.

PREDICTABILITY OF RESPONSE.

If I was just doing gross maneuvering the predictability was really pretty good. I could pull up, stop on a desired g, and hold the g without any problem.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

When I tried to do tight tracking, and it was really noticeable with the target airplane, I bobbled the nose almost continuously. These were not really very big bobbles, mostly just a nuisance. In fact, when I looked at the pipper, it didn't really change much more than the size of the target airplane out there, but it was quite distracting and certainly reduced my tracking capability.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good. I could pull to the desired g, and hold it. If I was doing steady maneuvering there was absolutely no problem maintaining the g. Longitudinal control in turns was quite excellent except when trying to do tight tracking.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence made the airplane considerably worse than it was. When I tried to counter the little turbulence inputs, I bobbled the airplane considerably more than I did without the turbulence, so it did detract quite a bit.

GOOD FEATURES

The good features about the airplane were that I could pull lots of g; I could perform gross maneuvers with the airplane easily. The big objection, however, was the tendency of the airplane to set up a pitch oscillation, or bobble, anytime I tried to do a very small input with the stick. It particularly showed up in the tracking. I really couldn't figure out any way to stop the bobble. I just had to discipline myself to make nice smooth inputs, if I could, in the tracking. That's quite hard to do when the pipper is drifting off a little bit and you try to get it right back on the target.

CONFIGURATION 8A
EVALUATION FLT 3 (Cont.)

OBJECTIONABLE FEATURES

It wasn't easy, but I think you could do the job with this airplane. I think that the deficiencies were quite objectionable, but I think they could be tolerated. I wouldn't get all the bullets in the target but I think I would get some of them there. It really needs extensive improvement. I think anytime that you try to do anything precisely you will induce some undesirable motions. You really can't prevent them without some sacrifice of the tracking. Turbulence was quite a bit worse, more effort was required and it deteriorated my performance.

CONFIGURATION 8B WITH TGT PILOT A PR 7 PIOR 4 TR D
EVALUATION FLT 7

ABILITY TO TRIM

The ability to trim was really quite good. I could put the airplane in almost any attitude I wanted and it tended to stay right there.

STICK FORCES

Stick forces were satisfactory; it was quite a comfortable airplane to maneuver. Stick motion was barely noticeable; I thought that was good. I really saw no reason to reselect the gear ratio.

PREDICTABILITY OF RESPONSE

The response predictability was really good, for maneuvering, and I didn't have any problem with it until I attempted to track. Then it was one continuous medium- to high-frequency, low-amplitude, pilot-induced oscillation. So, the predictability of the response for gross maneuvering was quite good; I could pull g right up to the limits I wanted without over g-ing the airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

During the air combat maneuvering, the gross maneuvering was good. I could rap the airplane around and I flew it aggressively. But, when I attempted tracking, things went really bad. There was a tendency to just sit there and oscillate at this low amplitude and high frequency. I'm not sure that you would really hit anything, spray a lot of bullets around the sky but you wouldn't be very good at getting them to go where you wanted them. So the tracking capability was unacceptable, very poor.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good. During the turns, just holding turns, and just holding g if I wasn't tracking was really very good. Tracking, however, was very poor.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence seemed to have quite an effect on the airplane. It moved the nose around quite a bit and I found that I tended to accentuate the tendency to oscillate.

GOOD FEATURES.

The g capability of this airplane, the ability to perform gross maneuvers was excellent.

OBJECTIONABLE FEATURES

The inability to track with the airplane was objectionable. When I tried to track, I got an almost continuous oscillation. If I didn't move the stick it was great and it didn't oscillate, but as soon as I tried to make any kind of small correction, the nose would oscillate, so it was obviously unacceptable. No way could I get smooth tracking.

PRIMARY REASON FOR PILOT RATING

I'd say that it was not adequate for the mission. I don't think you would lose control of it, because all you would have to do is back off on the gain a little and the airplane would damp itself out quite well. There was a real strong tendency for pilot-induced oscillations; however, they were not divergent. They were, however, almost zero-damped constant amplitude. Turbulence had a moderate effect on what I was trying to do; more effort was required.

CONFIGURATION 8B WITHOUT TGT PILOT A PR 3 PIOR 1 TR B
EVALUATION FLT 28

ABILITY TO TRIM

The ability to trim was really quite good.

STICK FORCES

I thought the stick forces were nice; they were light. No second thoughts on the gearing. Stick motion was barely noticeable; I thought that was good also.

PREDICTABILITY OF RESPONSE

The initial response was a bit abrupt. The final response was predictable but there was a tendency to overshoot the desired pitch attitude slightly.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control and tracking capability were fair to good. I would overshoot just a little, but the airplane was well damped and I could move it back and forth and put the pipper pretty much where I wanted it. So, I guess I would have to say that the pitch attitude control and tracking capability were really both pretty good.

NORMAL ACCELERATION CONTROL

Normal acceleration control was excellent; a very maneuverable airplane. I could change g quite easily and predict exactly what I was going to get. The same thing applies to steep turns; the longitudinal control I thought was pretty good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances had only a minor effect on a high-frequency input; a little more effort was required, but really not much of a deterrent. I would say no significant deterioration on my performance.

INSTRUMENT FLIGHT PROBLEMS

Tracking the heads down displays (IFR) was not much of a problem. I could get the attitude from one point to another rapidly, but I did, as I've mentioned earlier, get a minor overshoot. The airplane was well-damped, though, and pretty much stopped where I wanted. So, I really didn't see anything on the IFR tracking that I hadn't seen VFR.

GOOD FEATURES

It was a very maneuverable airplane with good g control. Tracking was good.

OBJECTIONABLE FEATURES

There was a tendency for the initial response to be a little abrupt and I would overshoot the target when putting in an abrupt input.

PRIMARY REASON FOR PILOT RATING

The airplane was satisfactory; however, I didn't particularly like the abruptness and it tended to overshoot.

CONFIGURATION 8D   WITH TGT   PILOT A   PR 2   PIOR 1   TR C
EVALUATION FLT 5

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

Stick forces were quite light; satisfactory. Stick motion was barely noticeable. I thought it was good and I didn't see any need to try to reselect the gear ratio.

PREDICTABILITY OF RESPONSE

Predictability of the airplane response to pilot inputs was quite good, both initial and final.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

I had good maneuvering and tracking capability. I could keep the airplane headed where I wanted most of the time.

NORMAL ACCELERATION CONTROL

Normal acceleration control was good. During turns there was no problem with the longitudinal control. I thought that was quite good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence had a little effect, but not an awful lot; anyway it was a good airplane.

GOOD FEATURES

I liked the tracking capability and the lack of any PIO or disturbance during the tracking.

OBJECTIONABLE FEATURES

There were no really objectionable features.

PRIMARY REASON FOR PILOT RATING

It was a good airplane for the task. Turbulence moved the nose a little more than I would have liked. It was quite sensitive to turbulence, but nothing more than a minor deterioration in task performance.

CONFIGURATION 8D   WITH TGT   PILOT B   PR 2   PIOR 1
EVALUATION FLT 14

STICK FORCES

Stick forces felt good and stick position felt really good during the acquisition phase.

PREDICTABILITY OF RESPONSE

I could predict where the nose was going.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

In tracking it was pretty predictable and the nose attitude seemed to be tied pretty tightly to the stick. Random noise during tracking caused the pipper to wander, but I felt that I could keep the pipper pretty close to where I wanted with the random noise. What little time I had the pipper on the target during ACM, it was good.

CONFIGURATION 8D
EVALUATION FLT 14 (Cont.)

NORMAL ACCELERATION CONTROL

It didn't tend to over g. I could pull up and the nose would do just what I thought it should be doing and it didn't seem to over g. Acquiring the target felt good. I had no problems with longitudinal control during turns or during ACM.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Effects of turbulence were minor on tracking and insignificant during acquisition.

GOOD FEATURES

It was a good feeling airplane. It seemed to do what I wanted it to do at my command. I could pull back on the stick to start a climb, and the nose moved at the rate I was looking for; it felt good.

OBJECTIONABLE FEATURES

I didn't see any objectionable features.

PRIMARY REASON FOR PILOT RATING

It was satisfactory without improvement. Pilot compensation was not a factor for desirable performance in the acquisition phase. I wish I had had a little more time in the tracking phase to verify it, but the airplane looked awfully good in tracking. There was an increase of pilot effort with turbulence; in tracking, more effort was required but it was minor. There was no tendency for the pilot to induce any undesirable motions.

CONFIGURATION 12 WITH TGT PILOT A PR 2 PIOR 1 TR B
EVALUATION FLT 22

ABILITY TO TRIM

The trim was quite good.

STICK FORCES

Stick forces were satisfactory, at least at the levels I like. Stick motion was satisfactory, very small and barely noticeable. I saw no reason to reselect the gear ratio.

PREDICTABILITY OF RESPONSE

The airplane response was very predictable; I thought both the initial and final response was quite good. The initial response was a little sensitive, but certainly satisfactory.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the ACM was good. Tracking was good. I felt I had smooth tracking capability with the airplane and would have put a lot of bullets in the target.

NORMAL ACCELERATION CONTROL

Normal acceleration control was especially good. I liked the g capability and felt that I had real fine g control. Longitudinal control in turns was good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence seemed to have only a minor effect on the airplane. A little more effort was required to keep the nose pointed where I wanted, but nothing severe.

CONFIGURATION 12
EVALUATION FLT 22 (Cont.)

GOOD FEATURES

I liked the tracking capability of the airplane and the general feel in flying; the airplane was quite good.

OBJECTIONABLE FEATURES

There was a tendency to be a little sensitive in the initial attitude response.

PRIMARY REASON FOR PILOT RATING

I thought it was a good airplane, with negligible deficiences.

CONFIGURATION 12 WITH TGT PILOT A PR 3 PIOR 1.5 TR C
EVALUATION FLT 24

ABILITY TO TRIM

Ability to trim was quite good.

STICK FORCES

Stick forces and motion were satisfactory.

PREDICTABILITY OF RESPONSE

It was predictable. The only real problem was that the initial response was a little too abrupt. It would be good to have just a little hysteresis or breakout to make it a bit better, but in general it was a good maneuvering airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control during the air combat maneuvering was in general quite good, with a tendency to get an initial bobble when inputs were made abruptly during the tracking. The tracking capability was pretty good. Once established on target, with nice, smooth corrections, I could keep it there pretty well.

NORMAL ACCELERATION CONTROL

Normal acceleration control was great; just a tendency to get that initial bobble when I made an abrupt input.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence did not have a major effect on the airplane. It caused some deterioration in performance, but there was only a little more effort required with a minor deterioration in task performance.

GOOD FEATURES

I liked the g capability. I thought the tracking capability in general was good.

OBJECTIONABLE FEATURES

I objected to the initial sensitivity to the inputs, finding that it caused me to bobble every time I did something abruptly. That bothered me a little.

PRIMARY REASON FOR PILOT RATING

It was only mildly unpleasant; you could probably live with the bobble.

CONFIGURATION 12 WITHOUT TGT PILOT A PR 7 PIOR 3.5 TR C
EVALUATION FLT 29

ABILITY TO TRIM

Ability to trim was fair to good.

STICK FORCES

Stick forces were light initially, but okay. No second thoughts on the gearing. Stick motions were okay.

PREDICTABILITY OF RESPONSE

The airplane response was very abrupt initially, too abrupt to make nice, small, easy changes. I would invariably get a quite large response and tend to overshoot the target in both directions.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

It was not a very good tracking airplane. The final response seemed to be well damped, but not enough to provide acceptable tracking capability.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good; a very maneuverable airplane. I could pull lots of g and could maneuver nicely. Longitudinal control in steep turns was pretty good. I could control the g pretty well unless I tried to make an abrupt maneuver, like a tracking maneuver in the turn. Then invariably I would get too much g.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances moved the airplane around noticeably. More effort was required with at least a minor deterioration in my performance.

INSTRUMENT FLIGHT PROBLEMS

IFR, it was like flying an airplane with purely a step response. I couldn't do things very smoothly and consequently I would overshoot the command bar most of the time on the random tracking task. I was continually maneuvering the airplane much too far with my inputs and I couldn't stay with the needle very well. But I had seen this VFR, so I guess this doesn't show anything I hadn't already seen.

GOOD FEATURES

The airplane was quite maneuverable.

OBJECTIONABLE FEATURES

There was a real tendency to overshoot the target every time I tried to track. Attempts to make small maneuvers invariably produced quite large airplane motions. I never found any way to slow down the initial response. It was always abrupt; there was always a tendency to overshoot.

PRIMARY REASON FOR PILOT RATING

I didn't get adequate performance in the closed loop tight tracking task. There were undesirable motions resulting from abrupt inputs and I could not completely prevent them, even by sacrificing the task.

CONFIGURATION 13 WITH TGT PILOT A PR 2 PIOR 1 TR B
EVALUATION FLT 22

STICK FORCES

Stick forces and motion were satisfactory.

CONFIGURATION 13
EVALUATION FLT 22 (Cont.)

PREDICTABILITY OF RESPONSE

The airplane response was quite predictable both in the initial and in the final responses. I enjoyed flying it very much.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch attitude control was especially good during the air combat maneuvering. Tracking capability was good. I had the pipper on the target quite a bit. There was a tendency to bobble the nose just a little when I really tightened up on the task, but it was still satisfactory.

NORMAL ACCELERATION CONTROL

Normal acceleration control was excellent. I had good maneuvering capability and good, fine, g control. Longitudinal control in turns was good; no problems at all there. It was especially good during air combat maneuvering. The g capability and the tracking capability were good.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence or random disturbances caused only a minor problem; I thought I could contend with it reasonably well. It did require a little more effort, but no real deterioration in performance.

GOOD FEATURES

I thought the tracking capability and g control were good.

OBJECTIONABLE FEATURES

The one objection was a minor one, a tendency to bobble the airplane when flying tightly. I thought it was a little sensitive.

PRIMARY REASON FOR PILOT RATING

It was satisfactory and had negligible deficiencies.

CONFIGURATION 13 WITH TGT PILOT A PR 2 PIOR 1 TR B
EVALUATION FLT 24

ABILITY TO TRIM

Trim was excellent.

STICK FORCES

Stick forces were really quite good, nice and light. Stick motion was barely noticeable; therefore, I thought it was good.

PREDICTABILITY OF RESPONSE

The final response was quite predictable, I had real fine control of the g. The initial response, if anything, was a little abrupt. I felt I would like to have just a little breakout or friction to take the edge off, but in general it was a good airplane.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Pitch response was really good. I could tell that I was going to get just what I wanted. During the ACM, the attitude control was approaching the excellent category. I really enjoyed flying it. I thought the tracking capability was very good.

CONFIGURATION 13
EVALUATION FLT 24 (Cont.)

NORMAL ACCELERATION CONTROL

Normal acceleration control was excellent. There was, however, a tendency for the airplane to be a little sensitive in the initial response. Longitudinal control in turns during the ACM was quite good. I thought the tracking and the g control were excellent.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence had only a minor effect on the airplane; a little more effort was required, but there was no significant deterioration.

GOOD FEATURES

I really liked the g capability and the tracking capability.

OBJECTIONABLE FEATURES

There was only one minor objection -- a slight tendency to be abrupt in the initial response. It really didn't detract too much; tracking was pretty good.

PRIMARY REASON FOR PILOT RATING

I thought it was a good airplane.

CONFIGURATION 13 WITHOUT TGT PILOT A PR 7 PIOR 4 TR C
EVALUATION FLT 27

ABILITY TO TRIM

Ability to trim was in general very good.

STICK FORCES

Stick forces were nice and light; they were okay. I had no second thoughts on the gearing. Stick motions were quite small, not noticeable.

PREDICTABILITY OF RESPONSE

The initial response was really rapid and when I tried to stop the airplane on a point, invariably I got about a 4-cycle oscillation before I could really get it settled down. But when I didn't try to put it right on a point and just pulled it up there and stopped, the airplane was well damped. So whatever was happening was something that I was doing. In general, though, the airplane response was a little too rapid; it was almost like flying a pure step.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

The pitch attitude control and tracking capability were poor. The airplane just responded too rapidly and when I tried to put it right on a point I would get a very low-amplitude, high-frequency, pilot-induced oscillation out of it. So, I thought the tracking capability was not acceptable for the fighter mission.

NORMAL ACCELERATION CONTROL

Normal acceleration control was quite good. I could pull lots of g, and maneuver the airplane abruptly and rapidly with no problems. In turns, control of the airplane was good; I had good g control. There was no problem there. It was only when I tried to do a tight tracking task and do it in a fairly rapid manner that I had a problem.

CONFIGURATION 13
EVALUATION FLT 27 (Cont.)

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances moved the airplane a little bit. It was just a very low frequency motion of the airplane that didn't seem to cause very much of a problem. The airplane with the heads down display (IFR) was really abrupt and there was a tendency to overshoot the command needle and oscillate several times before I could get it settled down. If I went at it a little slower; in other words backed off on my gain, I could do a better job. But in general, I wasn't particularly pleased with the tracking performance. These were problems that I saw VFR, so I didn't think it showed anything too different.

GOOD FEATURES

In general, the maneuvering capability was a good feature; g control in general was good.

OBJECTIONABLE FEATURES

The objectionable feature was the strong tendency toward a low-amplitude, high-frequency, pilot-induced oscillation when attempting to track tightly. I really had to ease into things and not do things abruptly; it was just too much. It would really shake me and the airplane.

PRIMARY REASON FOR PILOT RATING

I wouldn't buy it for the fighter mission; I thought the tracking was just not adequate.

CONFIGURATION 14 WITH TGT PILOT A PR 8 PIOR 4 TR E
EVALUATION FLT 21

ABILITY TO TRIM

The ability to trim wasn't bad except that I did get structure vibrations anytime I tried to trim because of the very light forces.

STICK FORCES

Stick forces were satisfactory although if I had increased them a bit, I might have been able to hold the stick with a little firmer grip. As it was, I was flying the airplane with fingertip control. Stick motion was satisfactory, very small.

PREDICTABILITY OF RESPONSE

It was a very high frequency airplane and as soon as I made an input the airplane responded right away. When I tried to stop the airplane where I wanted, it almost invariably got into a pilot-induced oscillation.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

The pitch attitude control during the ACM was very poor. There was an almost continuous pilot-induced oscillation of low amplitude and high frequency during the whole time. The tracking capability was really nil, it was practically impossible to track.

NORMAL ACCELERATION CONTROL

I could pull g with the airplane without getting an oscillation. It was only when I tried to do something tightly that I had a problem. In the turns, I had the same problem; an almost continuous pilot-induced oscillation during the air combat maneuvering.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Turbulence really did move the airplane around. It really did exaggerate the nose excursions and the oscillations.

CONFIGURATION 14
EVALUATION FLT 21 (Cont.)

GOOD FEATURES

I wouldn't lose control of it, but controlling it in the context of the mission was certainly very poor.

OBJECTIONABLE FEATURES

It was just impossible to track; it was just one continuous, high-frequency, low-amplitude pilot-induced oscillation. I really couldn't stop the oscillations except to back off from what I was doing.

PRIMARY REASON FOR PILOT RATING

It was certainly an unacceptable airplane. It had major deficiences, primarily the continuous oscillations I was in. The oscillations were not divergent, but I couldn't do the mission and maintain what I considered to be control of the airplane. Turbulence was really bad. Best efforts were required and it made the task much worse.

CONFIGURATION 14 WITHOUT TGT PILOT A PR 7 PIOR 3 TR D
EVALUATION FLT 28

ABILITY TO TRIM

Ability to trim was good.

STICK FORCES

The forces were okay; on the heavier side, but still okay. I had no second thoughts on the gearing. The stick motions were barely noticeable; they were okay.

PREDICTABILITY OF RESPONSE

The initial response was quite abrupt, a little too abrupt, and the final response was a bit under damped. That created various problems in the tracking which I will talk about later.

PITCH ATTITUDE CONTROL/TRACKING CAPABILITY

Invariably I overshot and oscillated about the target anytime I did anything abruptly, which kind of destroyed the tracking capability. When in a steady flight condition with steady g it was okay, but when I tried to make a change I got a quite large and abrupt response followed by a 3- or 4-cycle oscillation before it settled down.

NORMAL ACCELERATION CONTROL

Normal acceleration control in general was good. It was a good airplane for high g maneuvering and fun to fly from that standpoint. I thought I had good control in steep turns.

EFFECTS OF RANDOM DISTURBANCE INPUTS

Random disturbances moved the airplane around considerably. More effort was required with at least a moderate deterioration in performance.

INSTRUMENT FLIGHT PROBLEMS

The (IFR) tracking task really showed up the tendency to overcontrol the airplane. I could really make it move from one spot to the next, but stopping it where I wanted was a bit of a problem. I didn't see anything IFR, though, that I hadn't seen VFR.

GOOD FEATURES

The general maneuvering capability of the airplane was quite good.

OBJECTIONABLE FEATURES

My major objection was one that makes the airplane unacceptable for the tracking mission, the tendency to overshoot the g and oscillate about the target anytime I did anything abruptly.

PRIMARY REASON FOR PILOT RATING

The tracking was just too poor.

Appendix II

PARAMETER IDENTIFICATION FROM THE FLIGHT TEST DATA FOR VARIOUS CONFIGURATIONS IN PHASE II

The short-period dynamic characteristics of Configurations II-1 through II-5 were identified from the flight test data at various flight conditions as defined in Table IX. An advanced parameter identification technique developed by Calspan (Ref. 11 and 12) was used to identify the stability and control derivatives, Z_α, Z_{F_S}, M'_α, M'_q, M'_{F_S}, and the two constants Z_o and M'_o which account for non-equilibrium initial conditions. The equations for the constant speed dynamics and the measurements are described by

$$\begin{pmatrix} \dot{\alpha} \\ \dot{q} \end{pmatrix} = \begin{pmatrix} Z_\alpha & 1 \\ M'_\alpha & M'_q \end{pmatrix} \begin{pmatrix} \alpha \\ q \end{pmatrix} + \begin{pmatrix} Z_{F_S} \\ M'_{F_S} \end{pmatrix} F_S + \begin{pmatrix} Z_o \\ M'_o \end{pmatrix} \qquad \text{(A. II-1)}$$

$$\begin{pmatrix} q_m \\ \alpha_v \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ K_v & -\frac{\ell_v}{V} \end{pmatrix} \begin{pmatrix} \alpha \\ q \end{pmatrix} + \begin{pmatrix} v_1 \\ v_2 \end{pmatrix}, \qquad \text{(A. II-2)}$$

* Prime signifies that the effect of $M_{\dot{\alpha}}$ derivative is included.

In the measurement equation (A. II-2), ℓ_v = 14.1 ft; K_v is the correction factor of the α vane; and V is the true airspeed. They are dependent on the flight conditions as listed below:

Flight Condition	V (ft/sec)	K_v (deg/deg)
0	455	1.68
1	505	1.70
2	625	1.75
2^1	625	1.75
2a	530	1.82
2b	560	1.72
3	685	1.82
4	420	1.68
5a	475	1.78
6	245	1.64

The measurement noises, v_1 and v_2, as expressed in terms of deg/sec and deg, respectively, were assumed to be zero mean with covariance function

$$\mathrm{cov}\left\{\begin{bmatrix} v_1(t_i) \\ v_2(t_i) \end{bmatrix}\begin{bmatrix} v_1(t_j), & v_2(t_j)\end{bmatrix}\right\} = \begin{pmatrix} 0.01 & 0 \\ 0 & 0.01 \end{pmatrix} \delta_{ij} \qquad \text{(A. II-3)}$$

The results of parameter identification are shown in Tables X and XII through XV, respectively, for Configuration II-1 through Configuration II-5. The response matchings are shown in the following figures. On these figures, the cross (+) represents data, and the solid line represents the computer fit to the data. The circle points are residues for α or q.

CONFIGURATION II-1

RUN NO.	FLIGHT NO.	FLIGHT CONDITION
6	1402	0
54	↓	1
23	↓	2^1
51	↓	2
24	1407	2b
51	↓	3

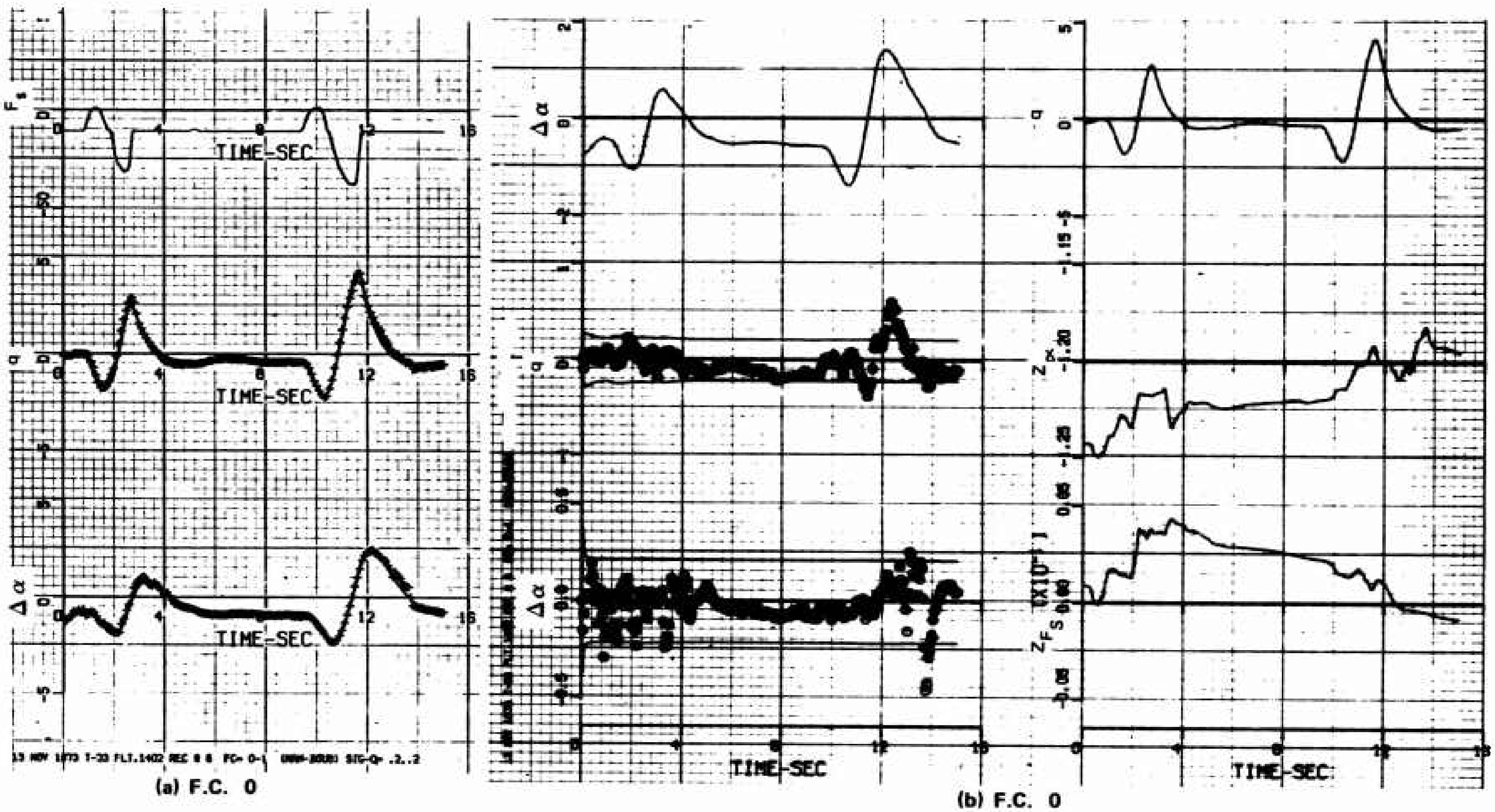
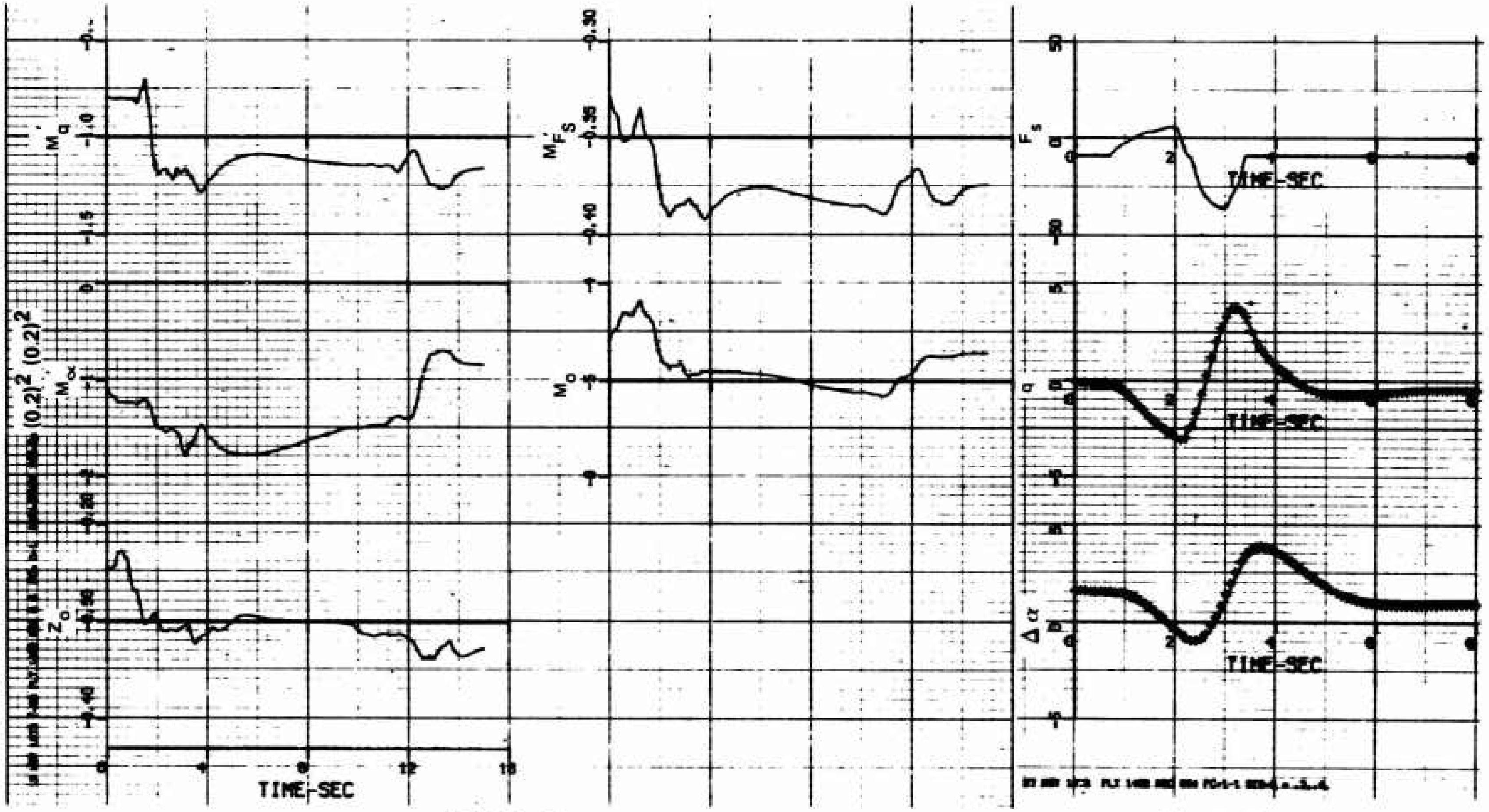


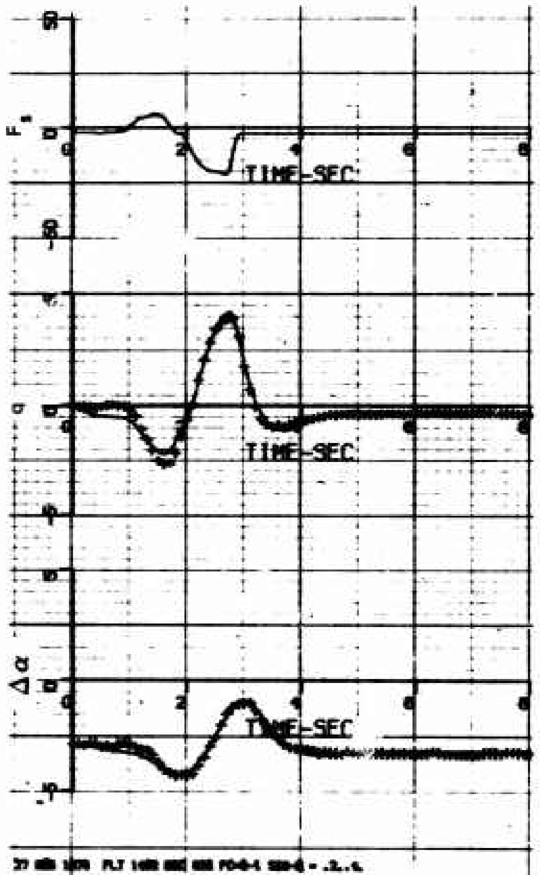
Figure II-1 COMPUTER IDENTIFICATION, CONFIGURATION II-1



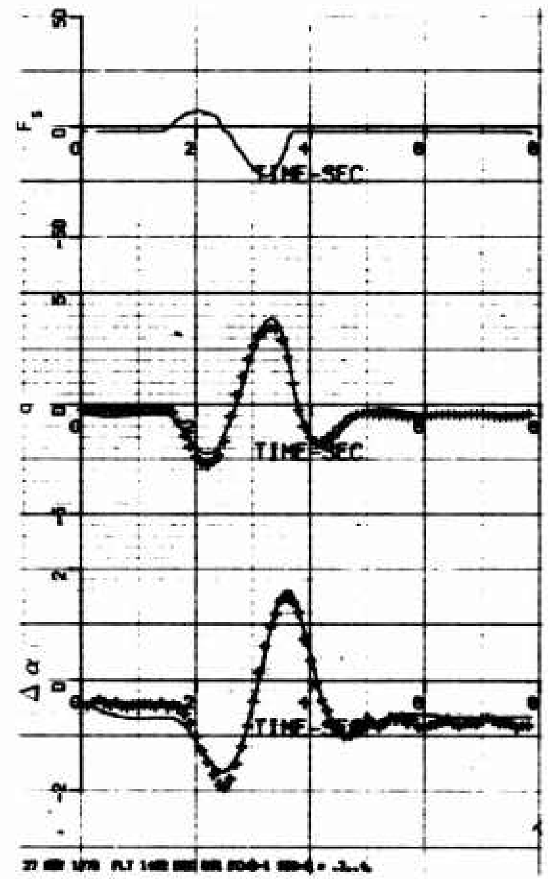
(c) F.C. 0

(d) F.C. 1

Figure II-1 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-1

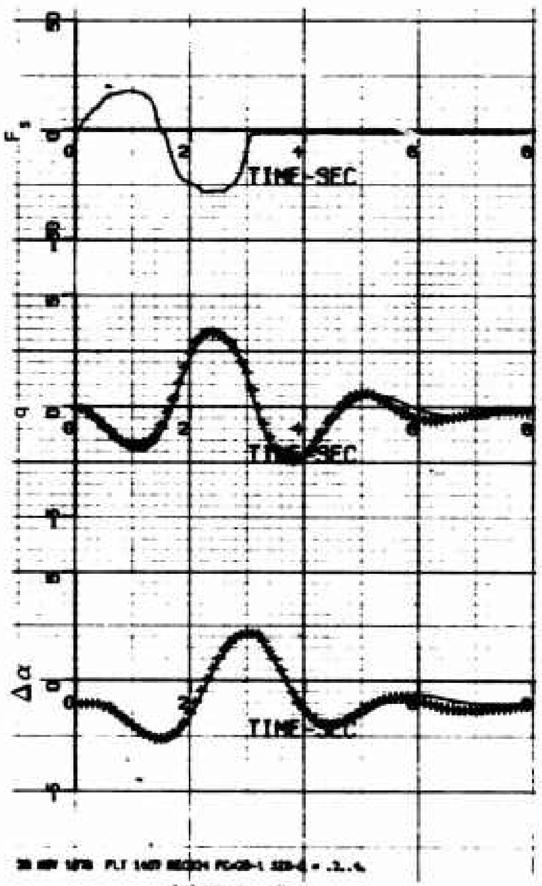


(e) F.C. 2[1]

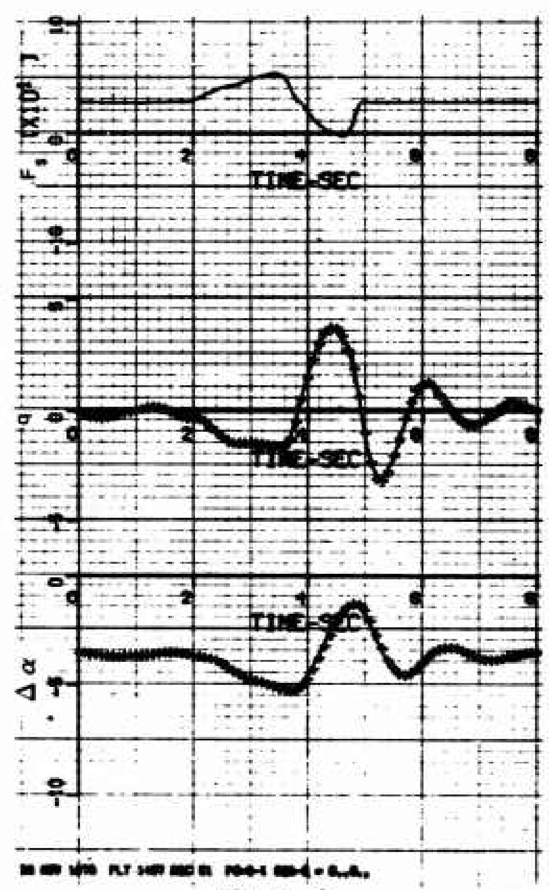


(f) F.C. 2

Figure II-1 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-1



(g) F.C. 2b

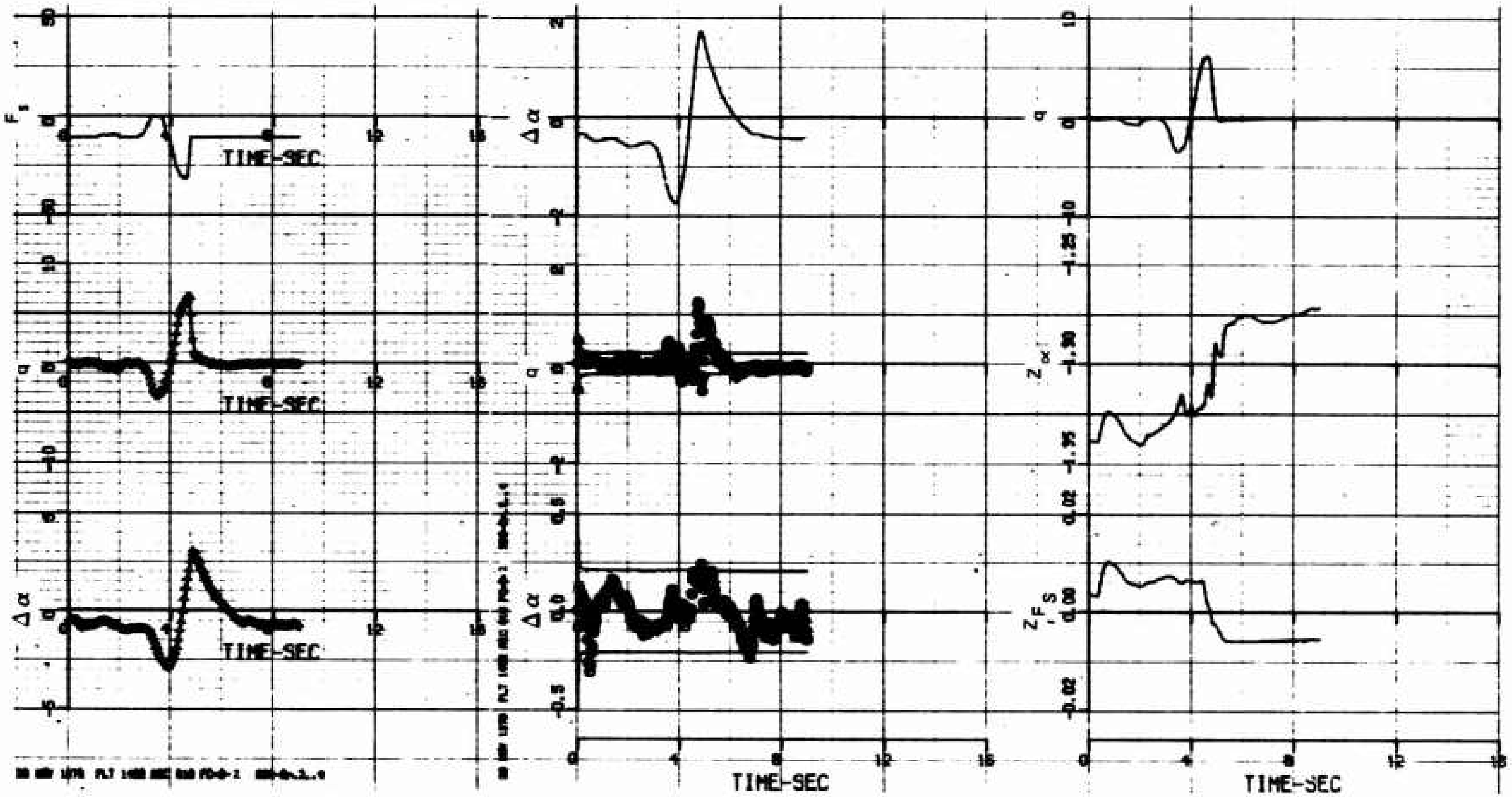


(h) F.C. 3

Figure II-1 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-1

CONFIGURATION II-2

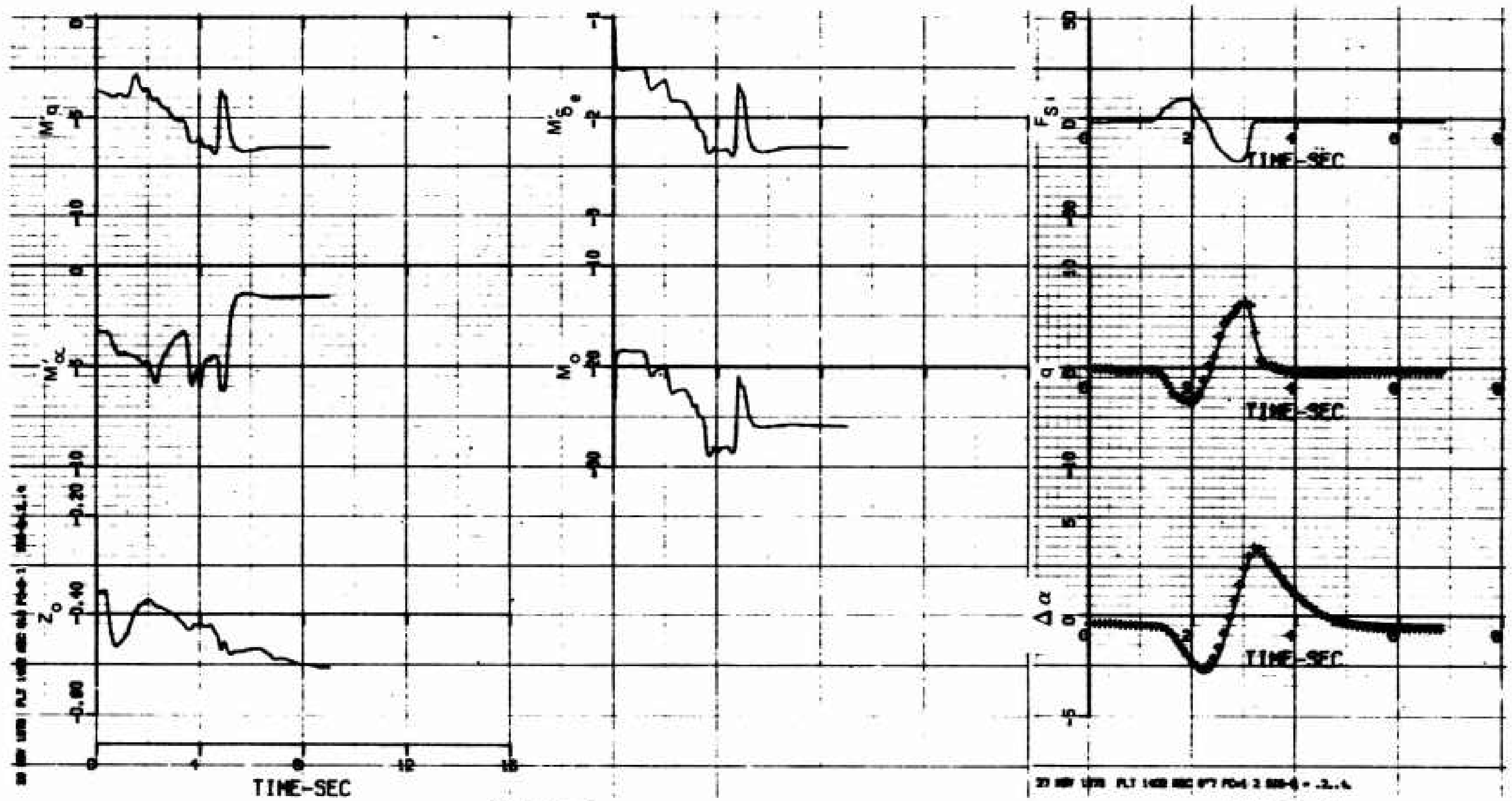
RUN NO.	FLIGHT NO.	FLIGHT CONDITION
10	1402	0
57		1
26		2[1]
48		2
20	1407	2a
27		2b
48		3
57		4



(a) F.C. 0

(b) F.C. 0

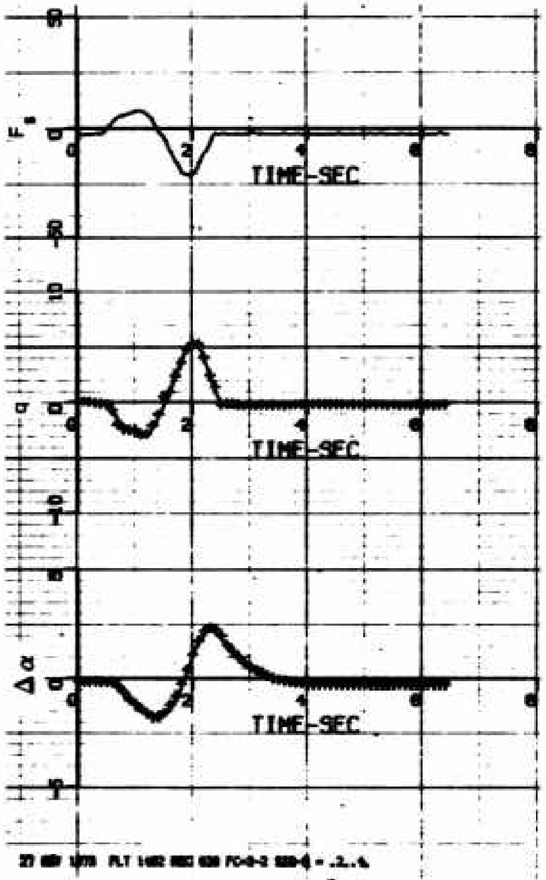
Figure II-2 COMPUTER IDENTIFICATION, CONFIGURATION II-2



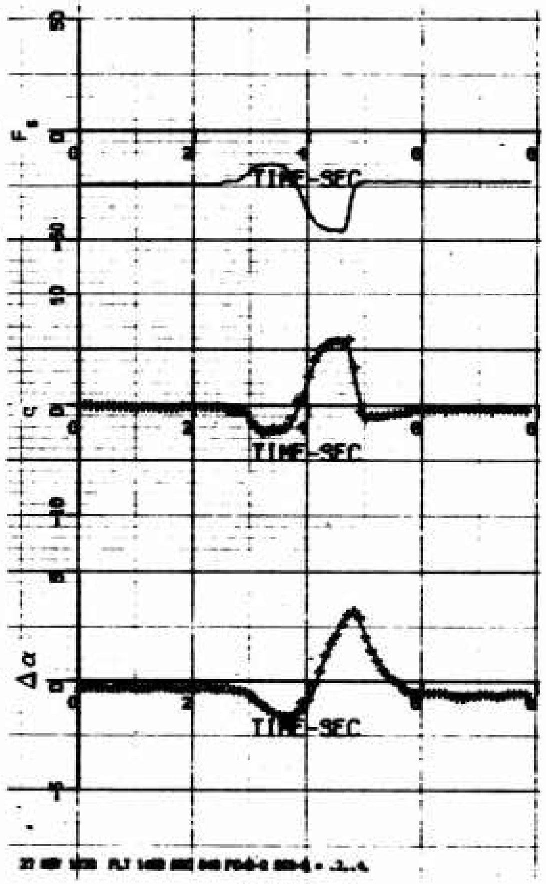
(c) F.C. 0

(d) F.C. 1

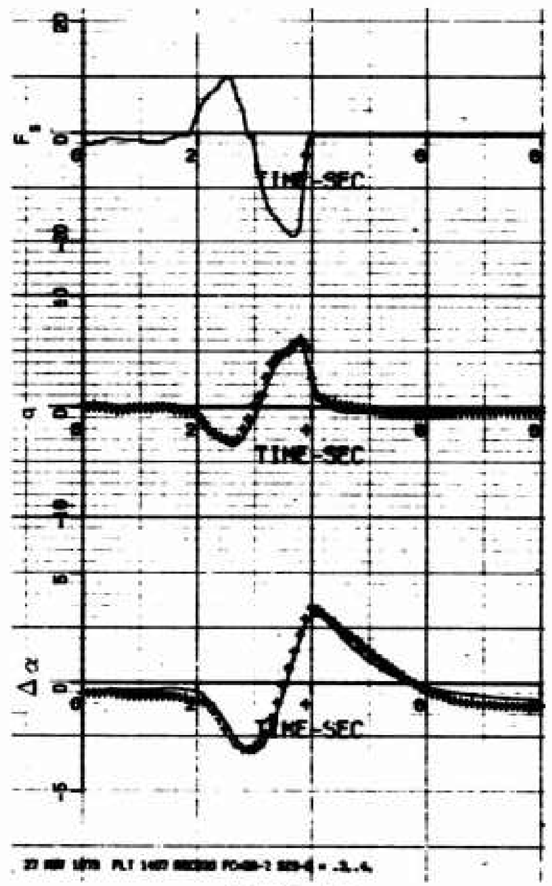
Figure II-2 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-2



(e) F.C. 2[1]

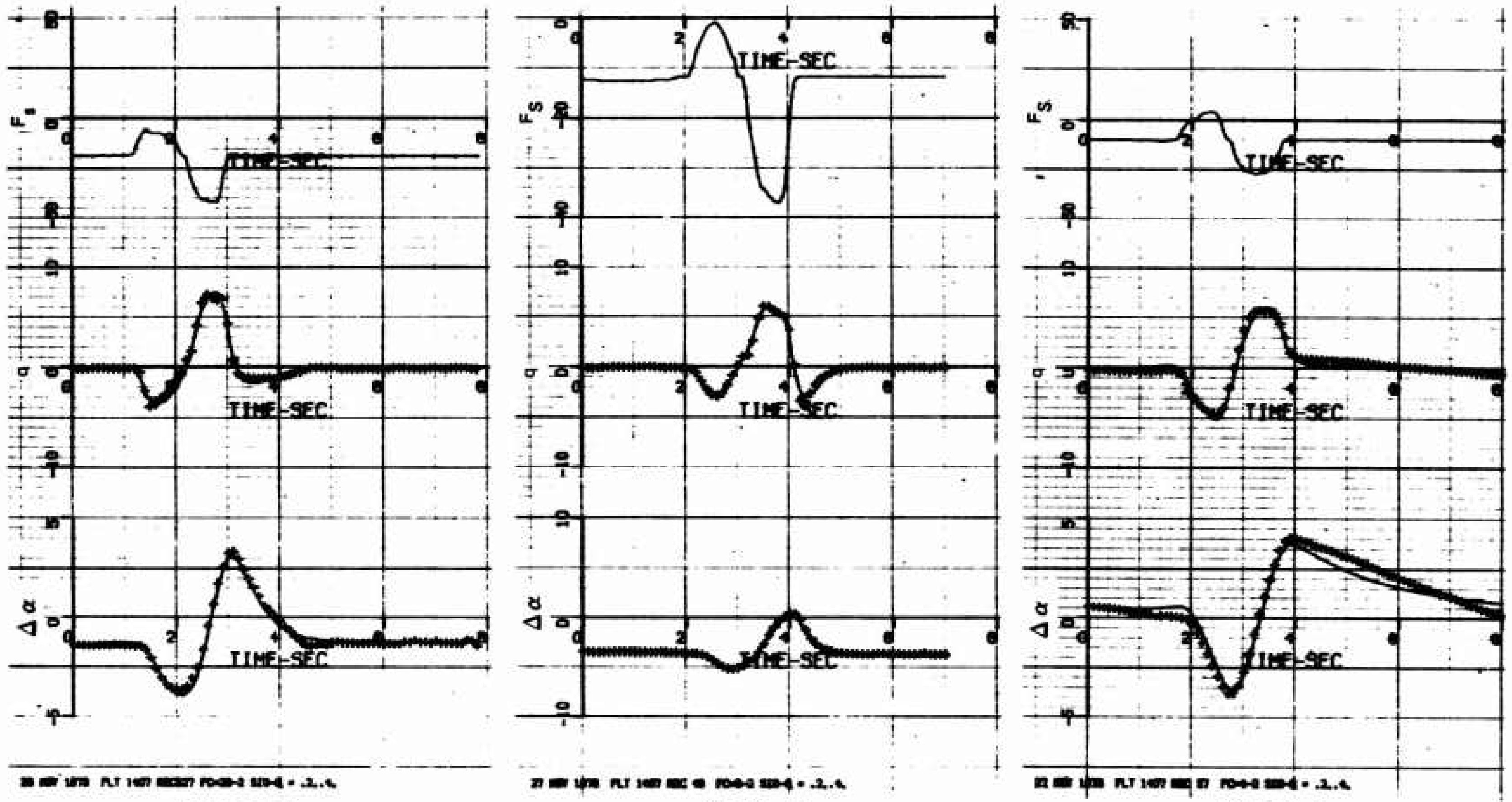


(f) F.C. 2



(g) F.C. 2a

Figure II-2 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-2



(h) F.C. 2b

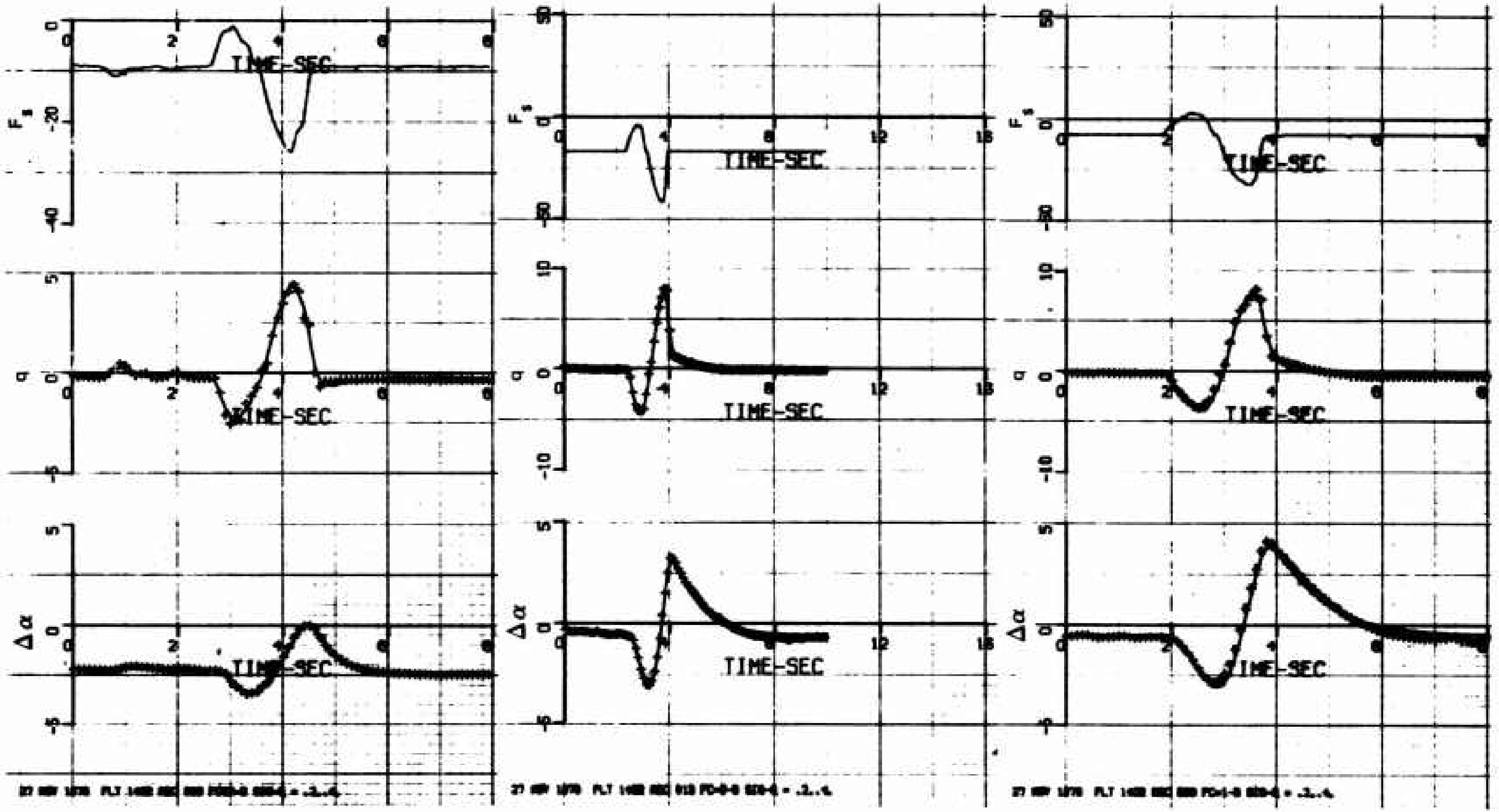
(i) F.C. 3

(j) F.C. 4

Figure II-2 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-2

CONFIGURATION II-3

RUN NO.	FLIGHT NO.	FLIGHT CONDITION
13	1402	0
59		1
29		2[1]
44		2
11	1407	2a
30		2b
45		3
60		4
69		5a

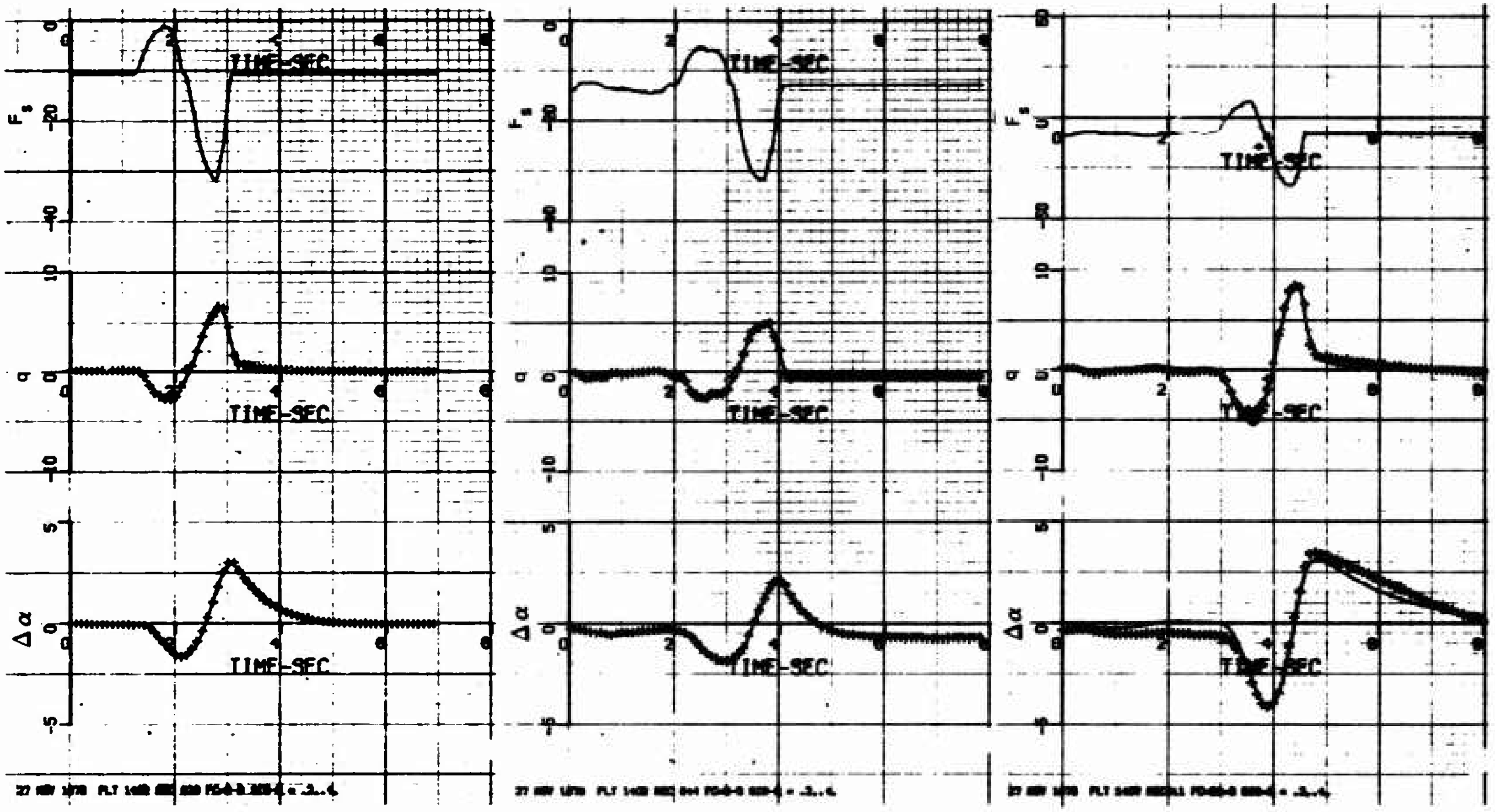


(a) F.C. 5a

(b) F.C. 0

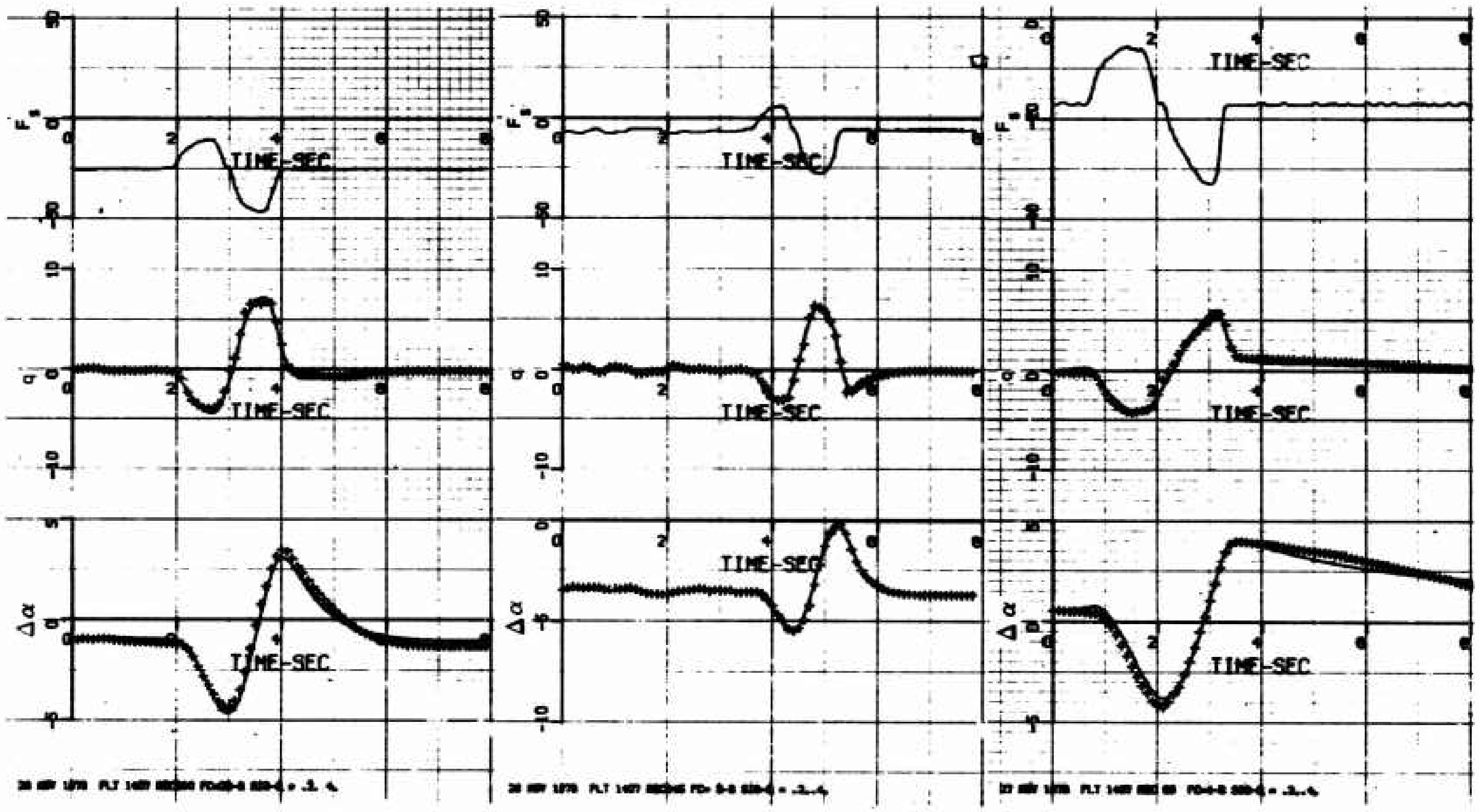
(c) F.C. 1

Figure II-3 COMPUTER IDENTIFICATION, CONFIGURATION II-3



(d) F.C. 2[1]　　(e) F.C. 2　　(f) F.C. 2a

Figure II-3 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-3

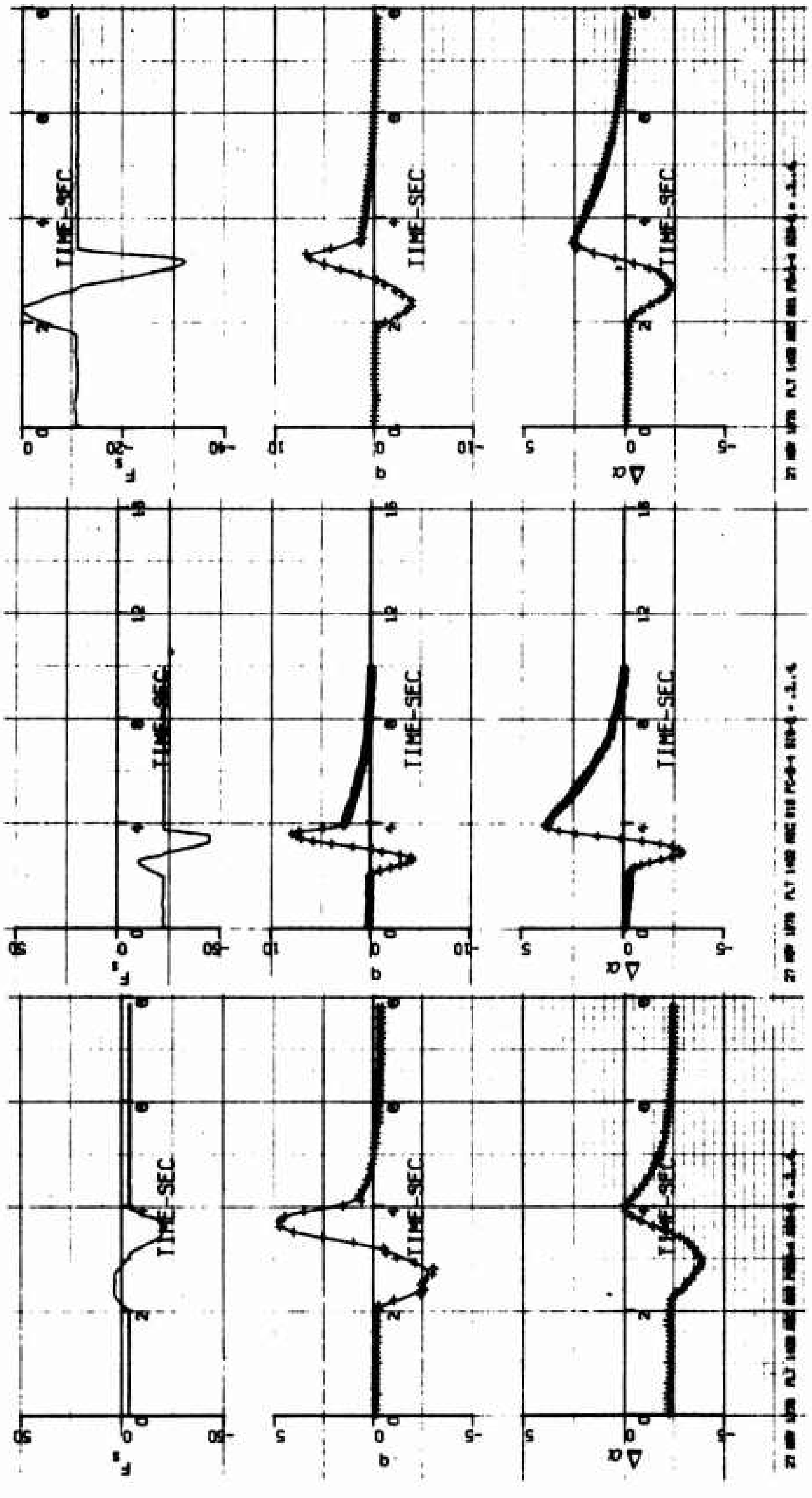


(g) F.C. 2b (h) F.C. 3 (i) F.C. 4

Figure II-3 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-3

CONFIGURATION II-4

RUN NO.	FLIGHT NO.	FLIGHT CONDITION
16	1402	0
61		1
32		2[1]
41	1407	2
33		2b
42		3
67	1402	5a

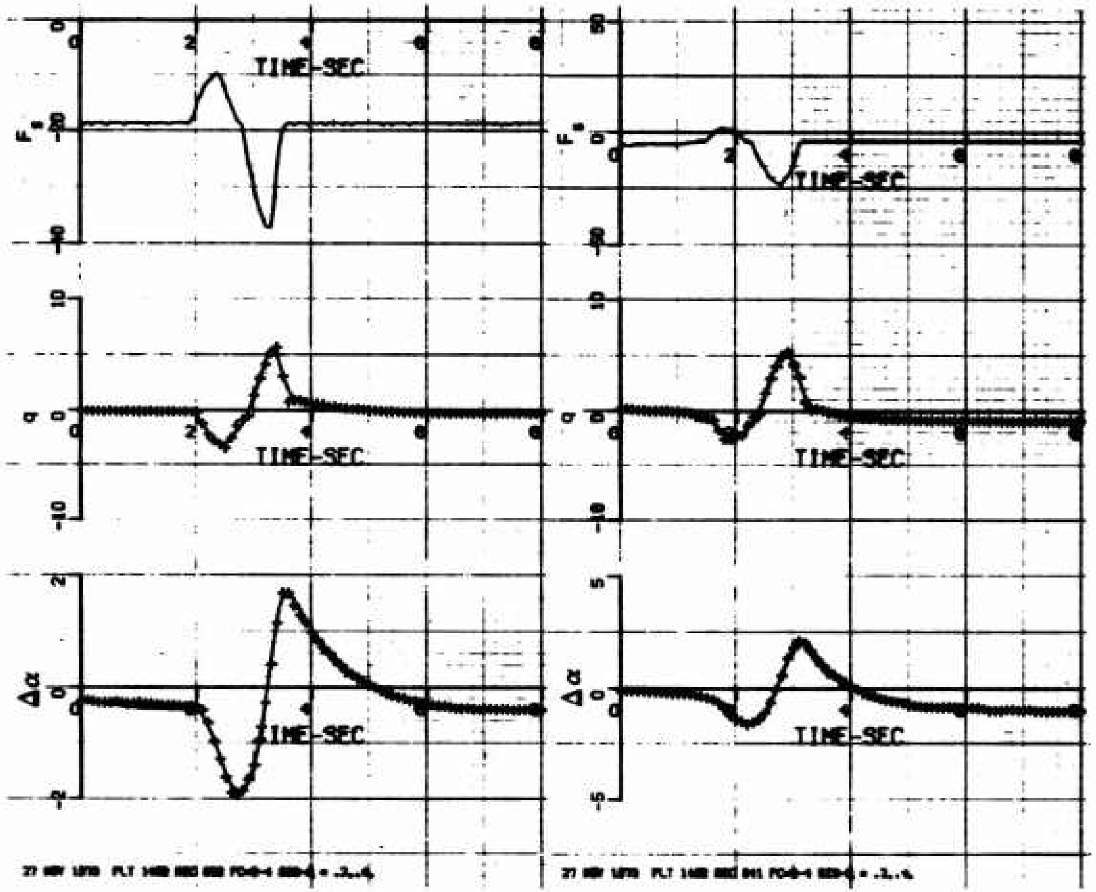


(a) F.C. 5a

(b) F.C. 0

(c) F.C. 1

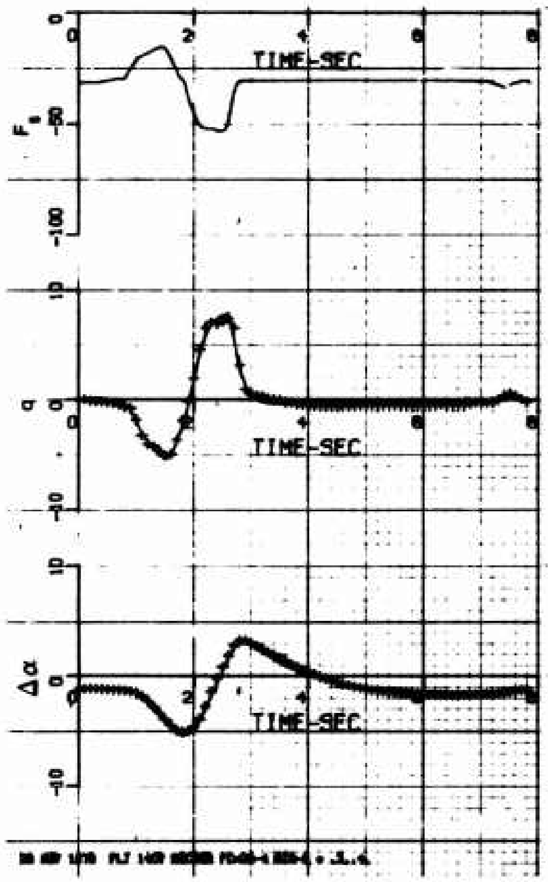
Figure II-4 COMPUTER IDENTIFICATION, CONFIGURATION II-4



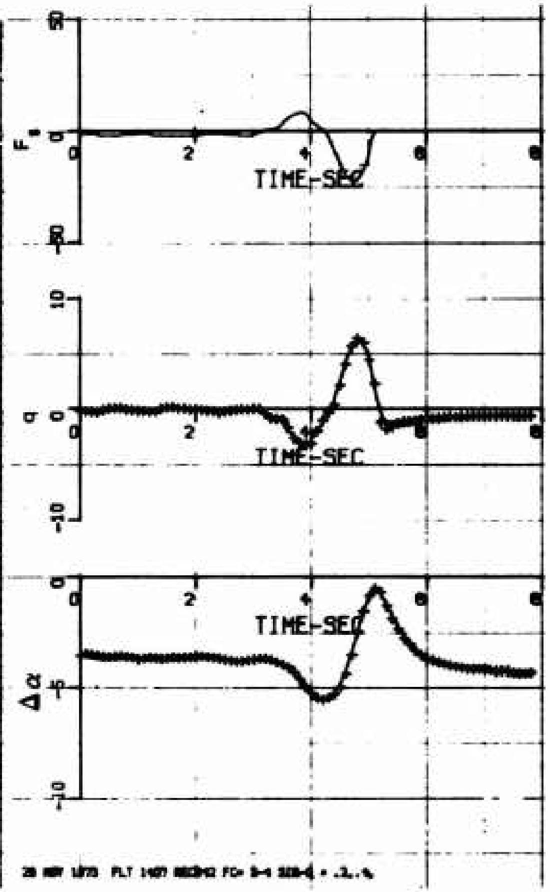
(d) F.C. 2[1]

(e) F.C. 2

Figure II-4 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-4



(f) F.C. 2b

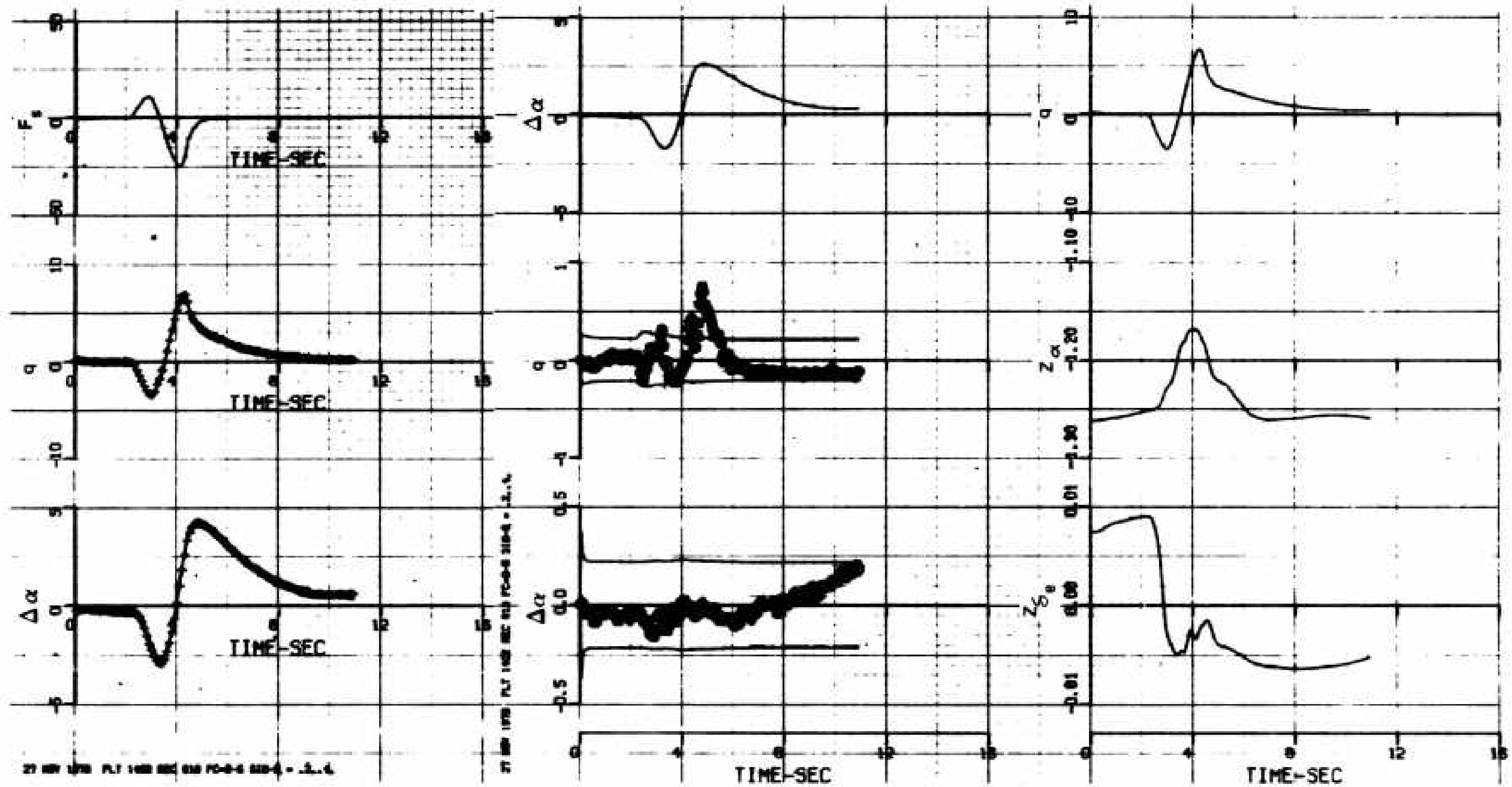


(g) F.C. 3

Figure II-4 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-4

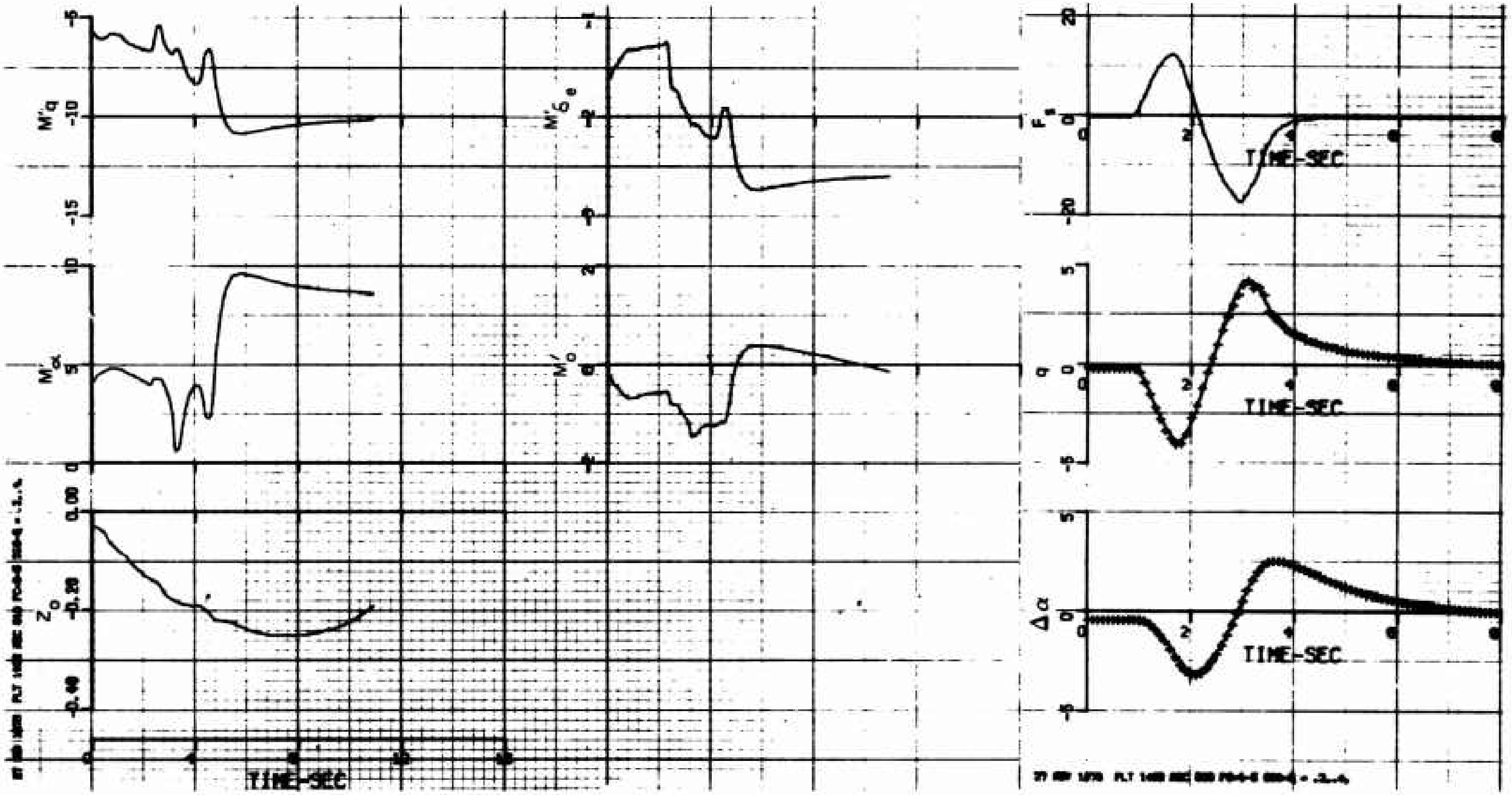
CONFIGURATION II-5

RUN NO.	FLIGHT NO.	FLIGHT CONDITION
19	1402	0
63		1
35		2[1]
38		2
65		5a
17		2a
56		2b
39	1407	3
69		6



(a) F.C. 0 (b) F.C. 0

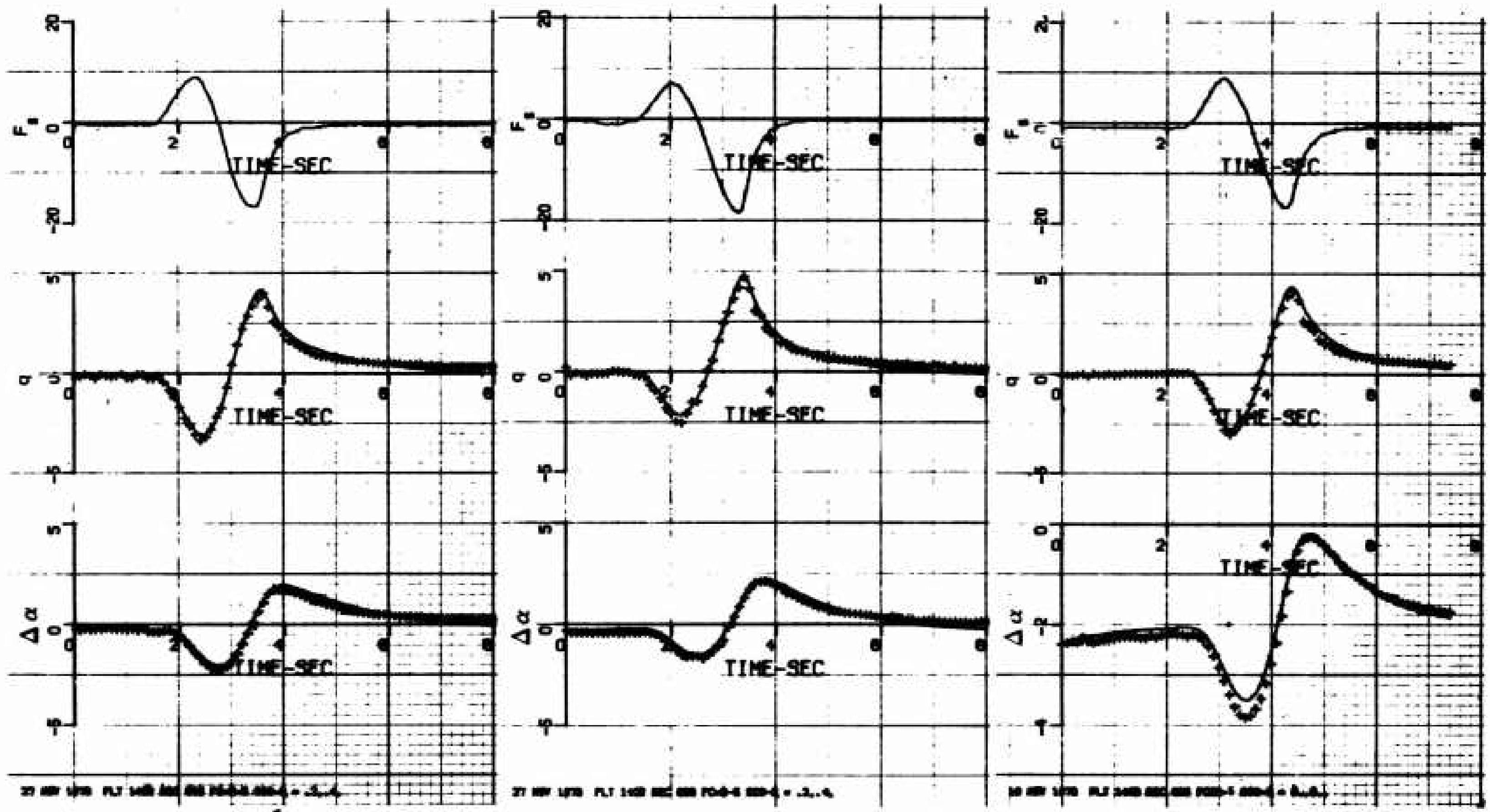
Figure II-5 COMPUTER IDENTIFICATION, CONFIGURATION II-5



(c) F.C. 0

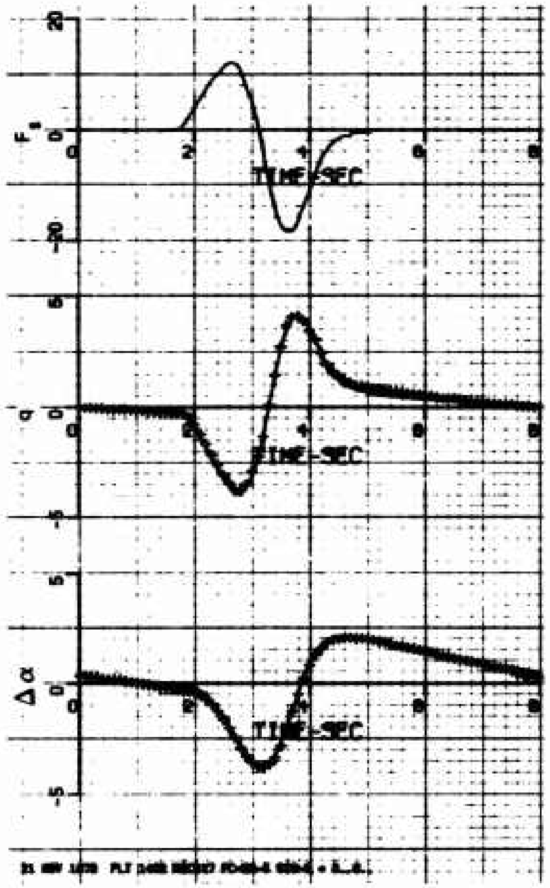
(d) F.C. 1

Figure II-5 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-5

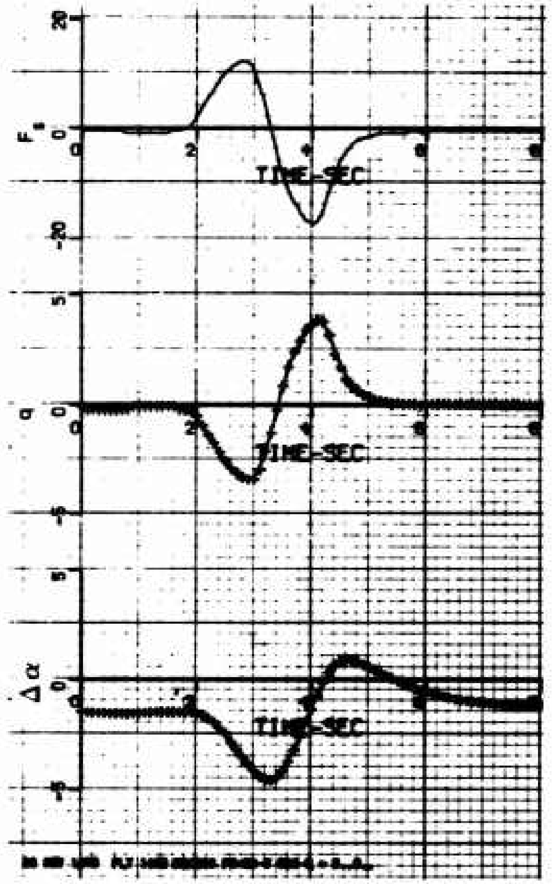


(e) F.C. 2[1]   (f) F.C. 2   (g) F.C. 5a

Figure II-5 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-5

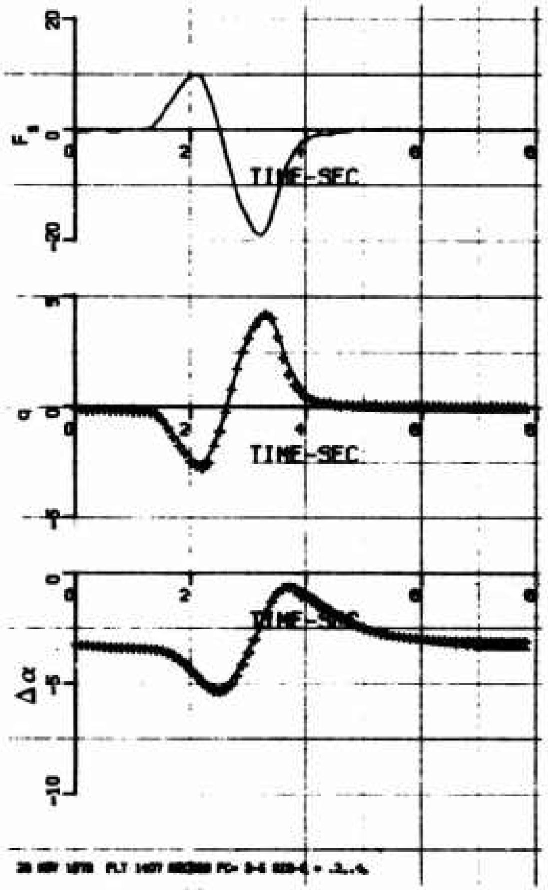


(h) F.C. 2a

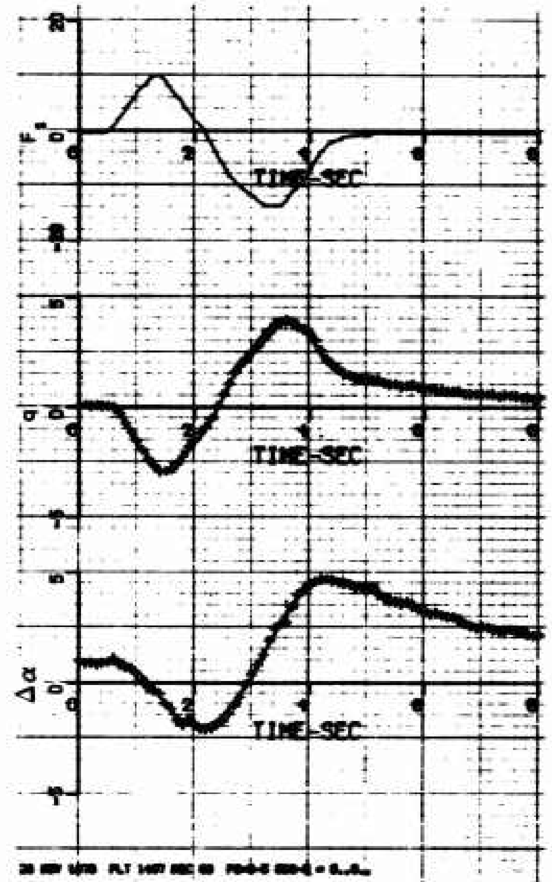


(i) F.C. 2b

Figure II-5 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-5



(j) F.C. 3



(k) F.C. 6

Figure II-5 (Cont'd) COMPUTER IDENTIFICATION, CONFIGURATION II-5

Appendix III

PILOT COMMENTS FROM PHASE II EXPERIMENT

This appendix contains pilot comments for each configuration evaluated in the Phase II experiment. The comments are arranged in numerical order, II-1 through II-5. For the reader's convenience, the configuraions are identified in the following list:

Configuration No.	CAS Configuration
II-1	Unaugmented Simulated Airplane
II-2	α, q System
II-3	α, n_z, q System
II-4	n_z, q System
II-5	n_z, q with proportional plus integral control and 4 rad/sec prefilter

For each configuration, the comments are in order; Pilot R followed by Pilot L. The pilot rating for each task and for the overall mission are shown with the comments for each task under each configuration.

CONFIGURATION II-1 PILOT R CONTROL SYSTEM CONFIGURATION: Unaugmented Sim. Acft.
EVALUATION FLT II-1 OVERALL PR 7.5

GROUND ATTACK: PR 5

Attitude Control/Tracking Capability

Pitch attitude control in the ground attack was really excellent in that it held the pitch attitude well. Going from one target to the next or taking care of the transient when changing pitch attitude was poor because of the slow response and the tendency to overshoot the target. I did sit like a rock on a given attitude, once established.

Attitude Transients at Bomb Release

The nose-up pitch attitude transient during bomb release was difficult to contend with because of the slow responding pitch control.

Normal Acceleration Control

There was an uneasy feeling that when I rolled in, I could easily dig in and overshoot the g. Pulling off the target, the forces were so huge for 1-1/2 incremental g that I didn't notice any tendency to over g with the high speed, but I did with the lower speed. So there seemed to be a difference as a function of speed.

Primary Reason for Pilot Rating

I think it is controllable; I think you can do the job. I don't think it is satisfactory, though, because the stick forces lightened at lower speeds. The generally sluggish pitch response was not satisfactory. The very heavy forces in the pull-out were not nice either. One feature it did have was the really solid pitch attitude when on the target providing that I happened to get on the target properly. It was considerably difficult to get on target.

AIR INTERCEPT: PR 7.5

Attitude Transients During Transonic Range

I did notice the transient in the transonic range. It was a poor airplane. I had a lot of difficulty in contending with even that tiny trim because the forces were enormous to make any changes or counteract any changes. So, the ability to control transients was poor.

Attitude Control/Tracking Capability

Pitch attitude control was just lousy. During the tracking task there was almost a constant oscillation.

Attitude Control at Low Speed, High Altitude

Around 170 knots, the low speed on this airplane was downright dangerous. Look away, and you could really wrap the airplane up. I had a great feeling of uneasiness flying this airplane. It was a sluggish airplane and the forces to level off at altitude almost required two hands. I thought the pitch attitude at low speed was poor. There was an uneasy feeling that the airplane was just going to stand on its tail. I had to be constantly trimming, and the trim wasn't fast enough to keep up with enormous forces as I tried to maneuver.

Trim Changes with Speed Changes

Based on the transient I saw in the transonic range, there were significant trim changes with speed changes. I was working all the time, but I didn't really just let the speed change and look at the trim change required.

Primary Reason for Pilot Rating

It was controllable. I don't think you can do an adequate job. I did not like the airplane. I don't think we could get adequate performance. I think that with a little in-attention, controllability might be in question.

AIR COMBAT MANEUVERING: PR 7

Normal Acceleration Control

There seemed to be a dramatic difference at 370 knots compared to 250 knots. At 250, it had a tendency to dig in and therefore a lack of precision in g. At 370, it seemed as if I could pull the g and didn't feel a tendency to overshoot, or dig in. So the normal acceleration control was different with airspeeds.

AIR COMBAT MANEUVERING: PR 7 (Cont.)

Attitude Control/Tracking Capability

The tracking capability was poor. I could not stop on the target and would end up in an oscillation. So, the initial response and the final response were not good. The stick forces were enormous throughout. At the lower speeds they tended to lighten up rather dramatically as I got the response going. At the high speed they were just huge; no good.

Predictability of Response

Predictability of response was poor.

Primary Reason for Pilot Rating

It was controllable. I don't think you could track anybody; I had difficulty maneuvering due either to the very high forces at high speed or to the lack of predictability at the lower speed.

LANDING APPROACH: PR 8

Attitude Control

Pitch attitude control was dangerous; very bad. The airplane looked unstable longitudinally. I could never find the trim point and the forces were really high. With a pitch attitude established, it would sit there, but if I made any changes, it was slow and felt like a giant spring flying. It slowly pitched up and the forces required to counteract the pitch up or pitch down, as the case might be, were really large. So it had dangerous pitch attitude control.

Speed Control

Speed control just followed along with the troubles in pitch attitude. My approach wasn't too bad but I was working a lot because of the forces and to stop the instability. It was not very comfortable. Any inattention and you are going to kill yourself.

Flight Path Control

Flight path control was good, but I wasn't really looking at it.

Missed Approach

No real problems with the missed approach in the sense that I was able to do it but the same difficulties I have already described were evident.

Primary Reason for Pilot Rating

There is some question what you really mean by controllability here. I would say that I could stop from crashing. I could do the job but I had to work at it so hard that I would not consider it an acceptable airplane. You could get the ILS done and get down there but I think that my tolerance was exceeded; it was beyond what I consider a tolerable pilot compensation. With any kind of distraction, and that's part of the game, you could be in serious difficulty with this airplane very quickly.

SUMMARY COMMENTS

Good Features

The one I can remember, which showed up particularly in the ground attack, was that once I had the pitch attitude it would stay there; however, getting it to the target and counteracting any transients was difficult with the sluggish pitch control.

Objectionable Features

The pitch control was generally sluggish; the forces were particularly heavy. At the lower speeds there was a tendency to over g; at 370 knots I didn't notice any over g tendency, but the forces required were very large. In the landing approach it seemed as if it was unstable, so constant attention was required and it wasn't very pleasant. In fact, it was a dangerous airplane in the landing approach in my opinion.

Primary Reason for Overall Pilot Rating

I don't think that adequate performance is attainable. The landing approach really deteriorates the airplane in my opinion.

CONFIGURATION II-1 PILOT L CONTROL SYSTEM CONFIGURATION: Unaugmented Sim. Acft.
EVALUATION FLT II-4 OVERALL PR 9

GROUND ATTACK: PR 7

Attitude Control/Tracking Capability

Once I got on the target, the pitch attitude control was no problem. When I changed targets, I had a nose bobble that was difficult to control

Attitude Transients at Bomb Release

There were no particular pitch attitude transients during bomb release, although the airplane became more stable.

Normal Acceleration Control

Normal acceleration control during target acquisition and tracking was not good. I had to push forward on the stick to hold an established g. Target acquisition was difficult. The main thing I encountered was the stick force reversal to hold the g, both on roll-in during target acquisition, and also a little on pull-out. However, on pull-out it seemed to be alleviated quite a bit once the bombs came off; no problem there.

Primary Reason for Pilot Rating

Major deficiencies, I would say. Adequate performance isn't attainable with tolerable pilot compensation. You've got to think too much about what you are doing.

AIR INTERCEPT: PR 7

Attitude Transients During Transonic Range

There was no particular problem in controlling whatever transients were there.

Attitude Control/Tracking Capability

Pitch attitude control and trackihg capability were extremely poor. I experienced overshoots. When supersonic, I noticed a definite stiffness in the control and it really hampered tracking ability. Every time I pulled up the nose or pushed over, there was a considerable lag before I saw anything happening, and that led to overshoots on the tracking task.

Attitude Control at Low Speed, High Altitude

The thing I noticed throughout was the excessive stick force; not particularly a lot of displacement but a lot of stick force.

Trim Changes with Speed Changes

There were some significant trim changes with speed changes. As I accelerated supersonic, I noticed that I had to put in a good deal of force, nose down.

Primary Reason for Pilot Rating

Adequate performance was not attainable with maximum compensation. I just couldn't really get the task done.

AIR COMBAT MANEUVERING: PR 6

Normal Acceleration Control

Normal acceleration control wasn't too bad. Not nearly so bad as when we had an aft c.g.

Attitude Control/Tracking Capability

Tracking capability was okay. Getting on a target was difficult. Once I was there, it was okay. On reversals, I had the same problem as in the Air Intercept Task.

CONFIGURATION II-1
EVALUATION FLT II-4 (Cont.)

AIR COMBAT MANEUVERING: PR 6 (Cont.)

Predictability of Response

It was predictable, but slow; it had excessive stick force.

Primary Reason for Pilot Rating

Adequate performance requires extensive pilot compensation.

LANDING APPROACH: PR 9

Attitude Control

Pitch attitude control was poor, extremely poor; the stick was very stiff. It turned into being a force stick, almost no displacement at all.

Speed Control

With marginal pitch attitude control, the speed control was very difficult.

Flight Path Control

The flight path was very difficult to maintain.

Missed Approach

There were no problems with execution of missed approach.

Primary Reason for Pilot Rating

I rated the approach as a deficiency that requires improvement. Intense pilot compensation was required to retain control, primarily in the area of pitch attitude control which really affects the speed and flight path control.

When you are close to the ground you should have an airplane that you can fly and not have severe problems with pitch control.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

I had to put in a considerable amount of trim in most phases of flight.

Stick Forces

The stick forces were by no means satisfactory; they were much too heavy.

Change in Stick Force with Speed

The stick force required for maneuvering did change with airspeed. Supersonic it was very sluggish. As we went subsonic in the air-to-air task, or ACM task, it seemed to improve somewhat. There was a lot of force with very little motion. I found this unsatisfactory.

SUMMARY COMMENTS

Primary Reason for Overall Pilot Rating

The overall rating was based mostly on the landing approach

CONFIGURATION II-2 PILOT R CONTROL SYSTEM CONFIGURATION: α , g
EVALUATION FLT II-1 OVERALL PR 3

GROUND ATTACK: PR 3

Attitude Control/Tracking Capability

The pitch attitude control was just a little bobbly in the fine control on the target, but I could settle it down without a lot of difficulty. It was surprisingly bobbly based on what I saw initially, just maneuvering it around.

Attitude Transients at Bomb Release

There was a mild pitch-up when I released the bombs, but I didn't have any difficulty controlling it.

Normal Acceleration Control

I didn't notice any particular problems. For general maneuvering to get in the ground attack profile, the airplane was okay. There was just a feeling of heaviness as if it were a highly damped or sluggish airplane, yet it did bobble on the target for very small corrections.

Primary Reason for Pilot Rating

I think you can do the job. I would say it was satisfactory with the mildly unpleasant characteristics I have already discussed.

AIR INTERCEPT: PR 2.5

Attitude Transients During Transonic Range

There was no noticeable transient in the transonic range and I certainly had no problem controlling the airplane.

Attitude Control/Tracking Capability

I could precisely control the attitude. The forces to do so seemed nice and light; no problems there.

Attitude Control at Low Speed, High Altitude

There was no difficulty with pitch attitude control at low speed and high altitude. No longitudinal control difficulties, and trimming seemed normal and adequate.

Trim Changes with Speed Changes

No significant trim changes with speed. There is just something about the control in terms of the heaviness when I am putting in big inputs that I don't really like, but it is much better than it was from my complaints before, the heaviness is not as severe now. On the tracking maneuvering the forces were good and it was precise, maybe one tiny overshoot. No other problems.

Primary Reason for Pilot Rating

I think it is satisfactory for this task, there was a peculiar thing that I can't describe as a factor of the forces in controlling the airplane in pitch which borders on a mildly unpleasant deficiency.

AIR COMBAT MANEUVERING: PR 4

Normal Acceleration Control

Normal acceleration control during ACM was very precise; no problems in getting the g I wanted.

CONFIGURATION II-2
EVALUATION FLT II-1 (Cont.)

AIR COMBAT MANEUVERING: PR 4 (Cont.)

Attitude Control/Tracking Capability

The tracking ability was good. I could stop the nose where I wanted and move it without any difficulties.

Predictability of Response

The initial response was just heavy, that was my problem with the airplane, which doesn't come out in the comments directly. The stick forces were just generally too heavy and to pull an incremental 1 g, I estimate that the forces got to be 10 to 15 lb. There was a slight feeling, on occasion a feedback on the stick, that I sort of got stick pumping. I felt something pushing on the stick occasionally which took away from the smoothness of applying the control input longitudinally. So the dominant thing was that the stick forces were just too heavy. The precision of the control was good. No problems. Tiny changes in pitch attitude, no problem; but in the gross maneuvering, it was the high stick forces that bothered me.

Primary Reason for Pilot Rating

I could do the job, I just had to work hard and my right arm got a little tired even with small incremental g. So, it was not satisfactory because of the high stick forces in the gross maneuvering.

LANDING APPROACH: PR 2.5

Attitude Control

Pitch attitude control during the approach was excellent.

Speed Control

Speed control was no problem.

Flight Path Control

Flight path control was good.

Missed Approach

I did notice a slight tendency to overcontrol in pitch. Pitch was very responsive and perhaps a little too much, although during the approach it was very easy to fly and there was a very smooth feel about the controls both laterally and longitudinally. Small changes in pitch attitude could be made precisely with no evidence of overcontrolling. A slight bobble was noticed on the flare and initiation of the go-around.

Primary Reason for Pilot Rating

I think it was satisfactory. The bobble that was noticed at the end, the little feeling of oversensitivity, degraded it slightly.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

No problems throughout.

Stick Forces

Stick forces were not satisfactory in the ACM and perhaps they were a little light on the go-around from landing approach. They seemed to be okay in the air intercept phase. Stick motion was satisfactory throughout.

CONFIGURATION II-2
EVALUATION FLT II-1

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS (Cont.)

Change in Stick Force with Speed

I am not sure in the ACM that I didn't see a tendency for the stick force to get really heavy as I slowed down but I really didn't see anything that I could positively identify.

SUMMARY COMMENTS

Good Features

Generally the precision of pitch attitude control was excellent throughout.

Objectionable Features

Objectionable features were the general heaviness of the stick forces in ACM and the little bit too light, too sensitive for pitch control, in the wave-off portion for the landing approach. There was also, during the ACM, occasionally some interference from the stick, some feedback to the stick. When relaxing forces and trying to change the pitch attitude it was noticeable. It didn't bother me doing the job.

Primary Reason for Overall Pilot Rating

I think overall it was a satisfactory airplane, It gets de-rated slightly because of the heaviness in ACM. I could do the job but it was uncomfortable.

CONFIGURATION II-2 (Repeat) PILOT R CONTROL SYSTEM CONFIGURATION: α , q_{γ}. (Repeat)
EVALUATION FLT II-3 OVERALL PR 2

GROUND ATTACK: PR 2

Attitude Control/Tracking Capability

There happened to be a single cloud sitting off and I tried to maneuver to it. The pitch control was very good, a tiny bobble near the end, but I could get it on the target. The pitch attitude control was excellent and ground tracking was good. No difficulties encountered.

Attitude Transients at Bomb Release

I noticed the pitch transients, but I could control the airplane very well on release.

Normal Acceleration Control

No problem with the normal acceleration control. I thought it was a very good airplane for the ground attack.

Primary Reason for Pilot Rating

I thought it was satisfactory.

AIR INTERCEPT: PR 2.5

Attitude Transients During Transonic Range

I didn't notice them.

Attitude Control/Tracking Capability

I noticed an initial abruptness whenever trying any aggressive maneuvering. It was a minor complaint but it was noticeable on occasion. As far as the tracking was concerned, I could track precisely. Maybe one overshoot but I could get the needle there quickly and with precision. The initial and final response were satisfactory.

CONFIGURATION II-2
EVALUATION FLT II-3 (Cont.)

AIR INTERCEPT: PR 2.5 (Cont.)

Attitude Control at Low Speed, High Altitude

Pitch attitude control at low speed was satisfactory; no complaints. No trim changes noticed.

Trim Changes with Speed Changes

No significant trim changes with airspeed were noticed.

Primary Reason for Pilot Rating

It was a satisfactory airplane for the air intercept phase. It was slightly degraded for the little bit of abruptness when initially making inputs.

AIR COMBAT MANEUVERING: PR 2.5

Normal Acceleration Control

Normal acceleration control was satisfactory. At high g, there was still a little kickback on the stick, a nibbling or sort of a pulsing on the stick which wasn't very comfortable.

Attitude Control/Tracking Capability

It was a little difficult to trim. Trying to move up to the horizon, I felt that I could, coming out of reasonably high g maneuvers, stop the pipper on the target with satisfactory precision.

Predictability of Response

Initial response and final response were both satisfactory.

Primary Reason for Pilot Rating

A little bit of bobble getting on the target but it was a satisfactory airplane.

LANDING APPROACH: PR 2

Attitude Control

Pitch attitude control was just excellent. It is unusual to have a responsive airplane like this in the landing approach. It was very responsive and the precision of pitch attitude control was outstanding. There was a little tendency to bobble on the go-around.

Speed Control

The speed control was good.

Flight Path Control

Flight path control was good.

Missed Approach

The sensitivity did show up just a little bit, but it was just a precise, smooth, responsive airplane.

Primary Reason for Pilot Rating

I think it was a good airplane; satisfactory. The only reason that it was not better was a little tendency to be too sensitive, but you would likely learn to fly it, quite well. It was just a little different than what I've ever seen on a landing approach.

CONFIGURATION II-2
EVALUATION FLT II-3 (Cont.)

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

No problems with trimming.

Stick Forces

I didn't really notice any problem.

Change in Stick Force with Speed

Stick force required for maneuvering didn't noticeably change with airspeed.

SUMMARY COMMENTS

Overall, the airplane was satisfactory.

CONFIGURATION II-2 PILOT L CONTROL SYSTEM CONFIGURATION: α, $\dot{g}$
EVALUATION FLT II-4 OVERALL PR 2

GROUND ATTACK: PR 3

Attitude Control/Tracking Capability

On the bombing run I had difficulty holding the pipper on the target. Every time I acquired the target, the nose would oscillate up and down and it was difficult to stabilize and pull to another target. During the acquisition and during the run, I had the same problem. The nose bobbled considerably. So I thought the pitch control was difficult.

Attitude Transients at Bomb Release

I didn't particularly notice any pitch transients during release. The plane did feel a little more stable when we released but it wasn't really noticeable.

Normal Acceleration Control

It was a little bit sensitive on the normal acceleration. I really felt it on the pull-out.

Primary Reason for Pilot Rating

I'd say the nose bobble was a mildly unpleasant deficiency. Some pilot compensation was required, and this degraded the airplane somewhat.

AIR INTERCEPT: PR 4

Attitude Transients During Transonic Range

I didn't notice any sensitivity change in pitch as the airplane accelerated through the transonic range.

Attitude Control/Tracking Capability

It didn't seem to overshoot a great deal; however, there were some overshoots.

Attitude Control at Low Speed, High Altitude

No comments.

Trim Changes with Speed Changes

I didn't notice any significant longitudinal control displacement, or force changes with speed. However, I could see it in trim.

CONFIGURATION II-2
EVALUATION FLT II-4 (Cont.)

AIR INTERCEPT: PR 4 (Cont.)

Primary Reason for Pilot Rating

Deficiencies warrant improvement because of the overshoot tendency.

AIR COMBAT MANEUVERING: PR 2

Normal Acceleration Control

Normal acceleration control during ACM was good.

Attitude Control/Tracking Capability

Tracking capability was very good. The pipper was steady during reversals, exceeding 60° of bank. Longitudinal control in turns was good, really good in fact.

Predictability of Response

Predictability of the aircraft response to ACM type maneuvering was good. It seemed to be just a little bit stiff, not quite as sensitive as maybe I would like for this type of maneuvering.

Primary Reason for Pilot Rating

I would call it good, with negligible deficiencies; i.e., I think it felt just a little bit stiff.

LANDING APPROACH: PR 2

Attitude Control

Pitch attitude control was really good. I felt perhaps a little bit of nose bobble, but not much; not to where it was not easily controlled. As a result of good pitch attitude control, speed control and flight path control were also good.

Speed Control

Speed control was good.

Flight Path Control

Flight path control was good.

Missed Approach

No problems in the execution of missed approach.

Primary Reason for Pilot Rating

It was good in this task.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

Ability to trim was good. In fact, not a great deal of trim was needed throughout the regime.

Stick Forces

Stick forces were most satisfactory. There were no large displacements. I barely noticed it on the approach. The stick didn't slop around, it was nice. It didn't require great movements to get a desired attitude.

SUMMARY COMMENTS

Primary Reason for Overall Pilot Rating

Based on my learning curve for the first maneuver, for the dive bombing, I would say that throughout the envelope it was good, with negligible deficiencies.

CONFIGURATION II-2 (Repeat) PILOT L CONTROL SYSTEM CONFIGURATION: α, g (Repeat)
EVALUATION FLT II-6 OVERALL PR 1

GROUND ATTACK: PR 2

Attitude Control/Tracking Capability

I had a difficult time trimming the lateral-directional, and encountered some pitch problems. There wasn't any particular problem once I got on the target. The nose seemed to bobble quite a bit during the run. The second run was better than the first, but not much.

Attitude Transients at Bomb Release

There were some pitch transients during target acquisition.

Normal Acceleration Control

Normal acceleration control throughout the maneuvers was no problem at all.

Primary Reason for Pilot Rating

I thought the negligible deficiency was the bit of pitch oscillation.

AIR INTERCEPT: PR 1

Attitude Transients During Transonic Range

Pitch attitude transients were negligible during the transonic range. The only difference I noticed was that the controls became a little stiffer. The pitch control was just a little bit stiffer during supersonic.

Attitude Control/Tracking Capability

The pitch attitude control and tracking capability were excellent.

Attitude Control at Low Speed, High Altitude

Pitch attitude control at low speed, high altitude was no problem at all; still good.

Trim Changes with Speed Changes

No significant trim changes with speed changes.

AIR COMBAT MANEUVERING: PR 1

Normal Acceleration Control

Normal acceleration control was excellent.

Attitude Control/Tracking Capability

Tracking capability was excellent.

Predictability of Response

Predictability of aircraft response was still excellent. Pilot rating during ACM was 1.

LANDING APPROACH: PR 2

Attitude Control

Pitch attitude control was excellent.

Speed Control

Speed control was excellent.

Flight Path Control

Flight path control was excellent.

CONFIGURATION II-2
EVALUATION FLT II-6 (Cont.)

LANDING APPROACH: PR 2 (Cont.)

Missed Approach

No problems with the execution of the missed approach.

Primary Reason for Pilot Rating

The only deficiency I saw with the system was that the stick force was just a little heavier than I would have liked.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability To Trim

I really didn't notice much need to trim the aircraft.

Stick Forces

Stick forces were slightly heavier as we went supersonic and also slightly heavier in the approach. It wasn't objectionable; I just prefer lighter stick force in the approach than what I had. However, it didn't interfere with the control of the aircraft in maintaining steady pitch attitudes.

Changes in Stick Force with Speed

Stick force required for maneuvering changed very little with airspeed. The little bit was perceptible and the change was acceptable. Stick motion was satisfactory.

SUMMARY COMMENTS

Overall I'd say this aircraft was very good; excellent.

CONFIGURATION II-3 PILOT R CONTROL SYSTEM CONFIGURATION: α, n_z, q
EVALUATION FLT II-2 OVERALL PR 2

GROUND ATTACK: PR 2

Attitude Control/Tracking Capability

Pitch attitude control during ground attack was just outstanding. I could really put it where I wanted and move it around quite nicely. No difficulties in tracking.

Attitude Transients at Bomb Release

I didn't even notice them at the drop point.

Normal Acceleration Control

During target acquisition, the forces were just puzzling. Sometimes they felt heavy and sometimes they felt all right. On the pull-out, for example, they were a little bit heavy to me although it was not a great problem. My only complaint was the stick force gradients. I would have liked them a little lighter at the higher speed on the pull-out.

Primary Reason for Pilot Rating

From what I saw, during the ground attack it was a satisfactory airplane.

AIR INTERCEPT: PR 2.5

Attitude Transients During Transonic Range

I didn't notice any pitch attitude transient going through the transonic range. So, the ability to control them was good, since I didn't notice any.

CONFIGURATION II-3
EVALUATION FLT II-2 (Cont.)

AIR INTERCEPT: PR 2.5 (Cont.)

Attitude Control/Tracking Capability

I thought tracking capability was very good.

Attitude Control at Low Speed, High Altitude

It started to get a little bit touchy at the lower speed, 170 knots. Very precise control, however, was a little bit sensitive.

Trim Changes with Speed Changes

I noticed myself having to trim quite a bit after slowing down, but it didn't seem abnormal.

Primary Reason for Pilot Rating

The precision tracking was excellent. Good airplane; the only problem I had was the slight problem with high sensitivities at the low speeds although the precision was excellent even at this sensitive control.

AIR COMBAT MANEUVERING: PR 2.5

Normal Acceleration Control

I really thought this was the best airplane I have seen in terms of the stick forces. I could really maneuver it. The only problem was a little tendency to jiggle on the g application. Obtaining the g that I wanted or stopping on the target, I got maybe one or two overshoots. It was just a little bit too sensitive but otherwise it was a real fine airplane to maneuver around.

Attitude Control/Tracking Capability

In tracking there was just a slight tendency to overshoot which detracted from an otherwise outstanding airplane.

Predictability of Response

Predictability of the initial response was great. Predictability of the final response left a little bit to be desired in terms of the little bobble at the end. However, I could get it on the target after one or two bobbles with no problem.

Primary Reason for Pilot Rating

I certainly thought it was satisfactory. However, I'll have to degrade it a bit for the little bobbles.

LANDING APPROACH: PR 2

Attitude Control

Pitch attitude control was excellent. There was a problem, however, with the trim. The last part of the approach and go-around I was out of aft trim, so I had to hold the force. The forces were quite light so it wasn't a problem but there was a little tendency to bobble, which I attributed to the trim. It had sensitive but very precise control. But with the trim problem, everytime I relaxed, the nose would fall down. I would get a little oscillation induced by the trim problem, which I chose to ignore and say that we should normally have trim and we can make that work.

Speed Control

Speed control was good.

Flight Path Control

Flight path control was good.

CONFIGURATION II-3
EVALUATION FLT II-2 (Cont.)

LANDING APPROACH: PR 2 (Cont.)

Primary Reason for Pilot Rating

It was satisfactory and I think it was a good airplane. If I didn't have that trim problem I'd likely rate it better but I'm not sure my interpretation of what I saw was due just to the trim.

SUMMARY COMMENTS

Good Features

The precision of pitch attitude control was outstanding. Force levels were generally good.

Objectionable Features

A little over sensitivity at low speeds and a little over sensitivity in the ACM precision tracking.

Primary Reason for Overall Pilot Rating

It was a good airplane, having only the minor pitch sensitivity problem.

CONFIGURATION II-3 PILOT L CONTROL SYSTEM CONFIGURATION: α, n_z, q
EVALUATION FLT II-5 OVERALL PR 1

GROUND ATTACK: PR 1

Attitude Control/Tracking Capability

It seemed to be quite sensitive on the roll-in. Once established on tracking it didn't seem to be too much of a problem. Pitch attitude control was not difficult and ground target tracking was relatively easy. It was easy to acquire different targets without too much pitch bobble.

Attitude Transients at Bomb Release

I didn't notice any particular transients during the bomb release. It was sensitive in pitch before release. The bobbles didn't interfere with the target acquisition and tracking.

Normal Acceleration Control

Normal acceleration control was good; no problem.

Primary Reason for Pilot Rating

It was good. There were no deficiencies; pilot compensation was not a factor.

AIR INTERCEPT: PR 1

Attitude Transients During Transonic Range

Air intercept was beautiful. Pitch attitude transients were negligible. I didn't even notice them when we went through Mach.

Attitude Control/Tracking Capability

Pitch attitude control and tracking capability were outstanding; no problem.

Trim Changes with Speed Changes

No significant trim changes with speed changes.

CONFIGURATION II-3
EVALUATION FLT II-5 (Cont.)

AIR COMBAT MANEUVERING: PR 1

Normal Acceleration Control

Normal acceleration control was beautiful.

Attitude Control/Tracking Capability

Tracking capability and longitudinal control were excellent. I noticed very little pitch bobble or oscillation at all; in fact, none.

Predictability of Response

Predictability of the aircraft response was excellent.

Primary Reason for Pilot Rating

An excellent airplane.

LANDING APPROACH: PR 2

Attitude Control

The pitch attitude control was good.

Speed Control

Speed control was really excellent. I noticed one thing; the stick forces were a little higher and the motion a little greater on the power approach than in the other tasks.

Flight Path Control

Flight path control was easy.

Missed Approach

No problems with the execution of the missed approach.

Primary Reason for Pilot Rating

I think there was a little deficiency, compared to the rest of the flight. Stick forces seemed to be somewhat increased, and the stick motion also increased a little. There was really no problem, though.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

Trim was excellent.

Stick Forces

Stick forces were more than satisfactory in fact, they were excellent.

Change in Stick Force with Speed

The stick force required for maneuvering changed very little with airspeed. During the ACM, I didn't wind up with a heavy stick force or the stick in my lap. So both the stick force and stick motion were satisfactory. In fact, they were excellent throughout the envelope.

SUMMARY COMMENTS

Primary Reason for Overall Pilot Rating

The airplane showed excellent characteristics throughout the envelope. I didn't consider the negligible deficiencies in the powered approach to be a real factor.

CONFIGURATION II-4 PILOT R CONTROL SYSTEM CONFIGURATION: n_z, q
EVALUATION FLT II-3 OVERALL PR 3

GROUND ATTACK: PR 3

Attitude Control/Tracking Capability

In tracking, there was a little tendency to bobble on the target. I could, however, get it on the target without difficulty.

Attitude Transients at Bomb Release

Transients were not noticeable.

Normal Acceleration Control

When turning in, there was just a slight feeling of lightening of the stick forces, a slight tendency to dig in. It gave me a little hesitancy about really pulling quickly into the maneuver. There was a slight tendency to overshoot.

Primary Reason for Pilot Rating

I could do the job all right. There was a slight tendency to bobble on the target. When pulling onto the target there was a little tendency to feel as if it were wrapping up. Pulling off the target, it felt quite good. During the climb-out, I seemed to spend a little time trimming it. It was a little difficult to find a precise trim. So I think you can do the job with it. I think it was satisfactory.

AIR INTERCEPT: PR 2.5

Attitude Transients During Transonic Range

No pitch attitude transients that I noticed. Control was not a problem.

Attitude Control/Tracking Capability

Pitch attitude in the tracking task was good. Tracking capability was good.

Attitude Control at Low Speed, High Altitude

I didn't notice anything with pitch attitude at low speed. Climbing up, I did notice that I got a little bit of wandering in trim although that seemed to improve as I got higher.

Trim Changes with Speed Changes

I didn't notice any significant trim changes with airspeed.

Primary Reason for Pilot Rating

It was a satisfactory airplane as far as the air intercept was concerned.

AIR COMBAT MANEUVERING: PR 4

Normal Acceleration Control

Normal acceleration control at high speed was excellent; very precise. Occasionally, at the higher g levels, there was a little feedback on the stick, which was kind of annoying. Precision of control was very good at high speed. At low speed, 250 knots, normal acceleration control lost some precision. There was a tendency to wrap up just a little bit, a feeling of lightness on the stick as I increased the g level. Precision of control, stopping the airplane on a target or maneuvering from target to target, was degraded somewhat. I could still, however, get the job done.

Attitude Control/Tracking Capability

Tracking capability was very good at high speed.

CONFIGURATION II-4
EVALUATION FLT II-3 (Cont.)

AIR COMBAT MANEUVERING: PR 4 (Cont.)

Predictability of Response

At high speed ($\approx$370 knots IAS), initial and final response were good. I could stop the airplane, from an abrupt maneuver, right on target.

Primary Reason for Pilot Rating

At high speed, it was just excellent; but the lower speed degraded it. Considering the low speed problems, I think these were minor, but annoying deficiencies because of the deterioration at low speed of pitch attitude control.

LANDING APPROACH: PR 3

Attitude Control

It didn't seem very stiff in pitch attitude on the landing approach, although there was no difficulty in doing the job. It didn't hold pitch attitude very well.

Speed Control

The speed control was satisfactory.

Flight Path Control

Flight path control was satisfactory.

Missed Approach

On the missed approach, I noticed a little abruptness with the input, but not a real problem. Coming into the landing approach, I noticed the trim was not as precise as other airplanes, and there was a tendency to be just working at trimming the airplane. On the missed approach, there was a tendency to overcontrol just a little.It was a minor observation, however.

Primary Reason for Pilot Rating

It was satisfactory.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

I think there was a degradation in my ability to trim, particularly at the lower speeds and in the landing approach.

Stick Forces

The tendency for stick forces to lighten in ACM was a problem. Otherwise the stick forces were okay. Stick motion was not a factor.

Change in Stick Force with Speed

There was a change in stick forces with airspeed in the ACM. I chose to call it unsatisfactory for that reason.

SUMMARY COMMENTS

Good Features

I could do the job with the airplane. I think it was generally satisfactory.

CONFIGURATION II-4
EVALUATION FLT II-3 (Cont.)

SUMMARY COMMENTS (Cont.)

Objectionable Features

The only objections I had were the tendency toward the lightening of the stick forces when speed was reduced in the ACM, and the wandering in the trim.

Primary Reason for Overall Pilot Rating

Overall, I think, the airplane was still satisfactory.

CONFIGURATION II-4 PILOT L CONTROL SYSTEM CONFIGURATION: n_z, g
EVALUATION FLT II-6 OVERALL PR 1

GROUND ATTACK: PR 2

Attitude Control/Tracking Capability

Pitch attitude control during ground tracking - presented no problem. Tracking was good; it was no problem to acquire and reacquire a target.

Attitude Transients at Bomb Release

There weren't any significant pitch attitude transients during the release although the airplane did feel more stable after release.

Normal Acceleration Control

Coming over the top it felt as if the stick force per g was pretty flat. In fact, I had to put on very little stick force in order to get the roll in g that I wanted. Normal acceleration control during target acquisition and tracking was no problem, but the flat stick force per g led to sensitive normal acceleration control which was somewhat objectionable.

Primary Reason for Pilot Rating

I'd rate it good with the normal acceleration control being a negligible deficiency.

AIR INTERCEPT: PR 1

Attitude Transients During Transonic Range

There weren't any significant pitch attitude transients; however, it did seem to become more pitch-sensitive as we went though Mach.

Attitude Control/Tracking Capability

Pitch attitude control and tracking capability were no problem at all; very little overshoot was encountered.

Attitude Control at Low Speed, High Altitude

Pitch attitude control at low speed, high altitude, was excellent; there weren't any longitudinal control or trim difficulties.

Trim Changes with Speed Changes

No significant trim changes with speed change, very little at all.

Primary Reason for Pilot Rating

No problem at all.

CONFIGURATION II-4
EVALUATION FLT II-3 (Cont.)

AIR COMBAT MANEUVERING: PR 1

Normal Acceleration Control

Normal acceleration control during ACM was excellent.

Attitude Control/Tracking Capability

Tracking capability was excellent.

Predictability of Response

Predictability of the aircraft response was excellent.

Primary Reason for Pilot Rating

Outstanding; no perceptible pitch transients or pitch bobble during the air intercept and ACM maneuvers.

LANDING APPROACH: PR 1

Attitude Control

Pitch attitude control felt real good. The nose seemed to wobble quite a bit but it was easy to maintain good steady instruments.

Speed Control

Speed control was excellent.

Flight Path Control

Flight path was excellent; no problem.

Missed Approach

No problems in the execution of the missed approach.

COMMENTS APPLICABLE TO ALL THE ABOVE TASKS

Ability to Trim

I didn't notice much need to trim at all. I could easily do whatever trimming was needed.

Stick Forces

Stick forces were more than satisfactory; they were quite light, very acceptable. It was very easy to control the airplane.

Change in Stick Force with Speed

The stick force required for maneuvering the airplane didn't change much at all. Stick motion was most satisfactory. The stick didn't move much; it didn't slop around, so I could precisely control the airplane.

SUMMARY COMMENTS

Primary Reason for Overall Pilot Rating

There was one negligible deficiency; the little bit of a flat stick force per g on the first maneuver, but other than that the airplane was excellent.

CONFIGURATION II-5 PILOT R CONTROL SYSTEM CONFIGURATION: n_z, g with P & I
EVALUATION FLT II-2 OVERALL PR 2

GROUND ATTACK: PR 4

Attitude Control/Tracking Capability

I didn't see any tendency to dig in. The airplane was reasonably sluggish in pitch control. However, on the ground attack I didn't have too many major complaints. Pitch attitude control during the tracking was good. Once on the target, it just stayed there solidly. There was a little bit of a tendency to overshoot the target because of the sluggish initial pitch response, but I could work it back to the target in good time and hold it on the target precisely.

Attitude Transients at Bomb Release

The bomb release did not present a problem. I didn't notice any transient; if there was one, I was able to control it.

Normal Acceleration Control

I just detected a little digging in tendency going in; nothing noticeable coming off the target. Stick forces on the pull-out were good.

Primary Reason for Pilot Rating

I didn't think the pitch response, initial response, was what I would consider satisfactory. So I would say it gave me minor but annoying deficiencies.

AIR INTERCPET: PR 2

Attitude Transients During Transonic Range

Nothing to comment on the transients.

Attitude Control/Tracking Capability

Pitch attitude control and tracking capability were excellent.

Attitude Control at Low Speed, High Altitude

Pitch attitude control at low speed was also excellent. Initial response and final response were well behaved. There were no trim problems.

Trim Changes with Speed Changes

I didn't notice any significant trim change with speed. As far as the high altitude was concerned, it seemed that on the way up, the precision was okay. The quickness, the initial response, seemed improved as we got higher and was good throughout the intercept phase.

Primary Reason for Pilot Rating

I think it was satisfactory in the intercept phase. I don't recall doing any compensation; it was a nice light airplane, responsive and precise.

AIR COMBAT MANEUVERING: PR 2

Normal Acceleration Control

Normal acceleration control was excellent.

Attitude Control/Tracking Capability

Tracking was just unbelievable. You could come from a high g pull-up and stop it on a cloud, and it wouldn't even wiggle one pipper width.

CONFIGURATION II-5
EVALUATION FLT II-2 (Cont.)

AIR COMBAT MANEUVERING: PR 2 (Cont.)

Predictability of Response

The predictability was excellent. In the initial response, the forces felt a little heavy initially, and then lightened up slightly. So that wasn't quite ideal, but I could hold g levels within tenths of a g very easily. And as I said, I could stop it on the target amazingly well. But a sort of modulation of the stick forces was noticeable. It was satisfactory, though.

Primary Reason for Pilot Rating

It was certainly a satisfactory airplane, but the force changes preclude it from being excellent.

LANDING APPROACH: PR 1

Attitude Control

Pitch attitude control was excellent.

Speed Control

Speed control excellent.

Flight Path Control

Flight path control was excellent. It was just a great airplane flying down the approach.

Missed Approach

The forces were noticeable on the missed approach, but that was kind of nice because it just felt solid. So I thought it was a very fine airplane on the landing approach.

Primary Reason for Pilot Rating

It was a very satisfactory airplane.

COMMENTS APPLICABLE TO ALL TASKS

Ability to Trim

Ability to trim was good all the way around.

Stick Forces

I seemed to notice some sluggish pitch response when I first took it at 250 knots and 5,000 ft. I seemed to notice a slight tendency to lighten up in some portions of the ACM. Stick motion was satisfactory.

Change in Stick Force with Speed

I didn't notice any real stick force changes with the airspeed.

SUMMARY COMMENTS

Good Features

It was a solid feeling airplane particularly in the landing approach. In general, the predictability of pitch response was outstanding.

Objectionable Features

There were some problems with the stick force modulation in ACM, and the pitch response was sluggish when I first evaluated it in the ground attack. Initial response was not satisfactory in the ground attack and that detracted from the predictability. If after flying it a long time, it seemed to get better as we were doing different things and flying at different altitudes and speeds.

CONFIGURATION II-5
EVALUATION FLT II-2 (Cont.)

SUMMARY COMMENTS (Cont.)

Primary Reason for Overall Pilot Rating

It was generally a very good airplane.

CONFIGURATION II-5 PILOT L CONTROL SYSTEM CONFIGURATION: $n_z \cdot q$ with P + I
EVALUATION FLT II-5 OVERALL PR 2

GROUND ATTACK: PR 3

Attitude Control/Tracking Capability

Pitch attitude control for ground target tracking seemed a little difficult. I think the primary reason why I had trouble was that the forces seemed to be a little high, and I got a little bit of overshoot. When I acquired a target and then went to another target, the airplane tended to have a slow overshoot and then stabilize. Once on the target, it wasn't any problem; it was steady on target.

Attitude Transients at Bomb Release

I couldn't really notice any pitch attitude transients during release. I do know that as I rolled in, it felt as if stick force per g started to flatten out and I had to push a little bit during the roll-in.

Normal Acceleration Control

Normal acceleration control during target acquisition and tracking was not too bad. I think it would have been easier had the stick forces been a little bit lighter.

Primary Reason for Pilot Rating

It had some mildly unpleasant deficiencies primarily due to the stick force, but minimum pilot compensation was required.

AIR INTERCEPT: PR 3

Attitude Transients During Transonic Range

There were no significant pitch transients as we went supersonic.

Attitude Control/Tracking Capability

The pitch attitude control was degraded very slightly by the slightly heavy stick forces, and led to very mild overshoot if I pursued the tracking aggressively. This was not a very serious deficiency, however.

Attitude Control at Low Speed, High Altitude

There were no longitudinal control or trim difficulties at high altitude; in fact, it felt very stable. It was very easy to control both high- and low-speed at high altitude.

Trim Changes with Speed Changes

No significant trim changes with speed changes.

Primary Reason for Pilot Rating

I would say that it required minimal pilot compensation. I had to slow down my stick inputs just a little bit to prevent overshooting.

CONFIGURATION II-5
EVALUATION FLT II-5 (Cont.)

AIR COMBAT MANEUVERING: PR 3

Normal Acceleration Control

Normal acceleration control was excellent.

Attitude Control/Tracking Capability

Tracking capability was excellent.

Predictability of Response

The predictability was good, to fair. Once it was on target, it was really good, but when I was searching back and forth acquiring a target, it led to some overshooting.

Primary Reason for Pilot Rating

The tendency to overshoot was a minor deficiency.

LANDING APPROACH: PR 2

Attitude Control

Pitch attitude control was excellent.

Speed Control

Speed control was no problem.

Flight Path Control

Flight path control was good.

Missed Approach

The missed approach was no problem.

Primary Reason for Pilot Rating

I would say it had negligible deficiencies, mainly the stick force was heavier at low speeds in the power approach.

SUMMARY COMMENTS

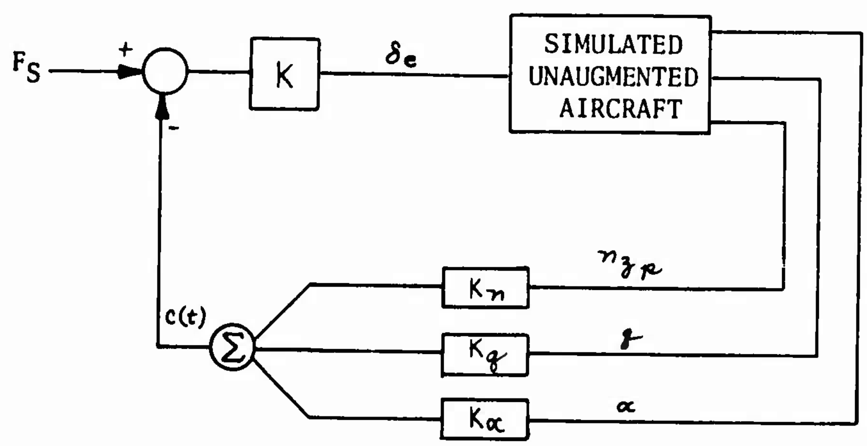
Primary Reason for Overall Pilot Rating

I would say that the overall rating would be good. It seemed to have minimal deficiencies. The only comment I really have was the slightly high stick forces were more characteristics of an attack-type aircraft than a high performance fighter.

Appendix IV

DERIVATION OF EQUATIONS (6.17a) THROUGH (6.17c)

For $K_\iota = 0$ and with prefilter and sensor filters deleted (see Figure 42), the SCAS reduces to the following configuration:



In the above sketch, n_{z_p} is given by

$$n_{z_p} = n_{z_{cg}} + \frac{\ell}{g}\dot{q} \qquad \text{(A. IV-1)}$$

where ℓ = 12.5 ft. Neglecting the small Z_{δ_e} of the NT-33A, the transfer functions of the short-period dynamics are given by

$$\frac{\dot{\theta}}{\delta_e} = \frac{M_\delta\left(s + \frac{1}{T_{\theta_2}}\right)}{s^2 + 2\zeta_{SP}\,\omega_{SP}\,s + \omega_{SP}^2} \qquad \text{(A. IV-2)}$$

$$\frac{\alpha}{\delta_e} = \frac{M_\delta}{s^2 + 2\zeta_{sp}\,\omega_{sp}\,s + \omega_{sp}^2} \qquad \text{(A. IV-3)}$$

$$\frac{n_{z_p}}{\delta_e} = \frac{M_\delta \frac{l}{g}\left(s^2 + \frac{1}{T_{\theta_2}}\,s + \frac{V}{l}\,\frac{1}{T_{\theta_2}}\right)}{s^2 + 2\zeta_{sp}\,\omega_{sp}\,s + \omega_{sp}^2} \qquad \text{(A. IV-4)}$$

The transfer function $\frac{c}{\delta_e}(s)$ then becomes

$$\frac{c}{\delta_e}(s) = M_\delta\,K_n\,\frac{l}{g}\;\frac{s^2 + 2\zeta_1\omega_1\,s + \omega_1^2}{s^2 + 2\zeta_{sp}\,\omega_{sp}\,s + \omega_{sp}^2} \qquad \text{(A. IV-5)}$$

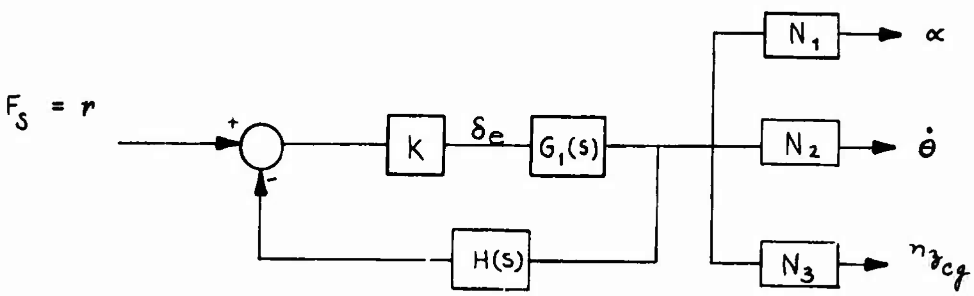
where

$$2\zeta_1\omega_1 = \frac{1 + \frac{1}{T_{\theta_2}}K_0}{K_0}$$

$$\omega_1^2 = \frac{\frac{K_\alpha}{K_g} + \frac{1}{T_{\theta_2}}\left(1 + \frac{V}{l}K_0\right)}{K_0}$$

$$K_0 \triangleq \frac{K_n}{K_g}\;\frac{l}{g}$$

The SCAS may now be represented by the following block diagram



where

$$G_1 = \frac{1}{s^2 + 2\zeta_{sp}\,\omega_{sp}\,s + \omega_{sp}^2}$$

$$N_1 = M_\delta$$

$$N_2 = M_\delta\left(s + \frac{1}{T_{\theta_2}}\right)$$

$$N_3 = \left(\frac{V}{g}\right)\left(\frac{1}{T_{\theta_2}}\right) M_\delta$$

$$H(s) = M_\delta K_n \frac{\ell}{g}\left(s^2 + 2\zeta_1\omega_1 s + \omega_1^2\right)$$

It is readily shown that

$$\frac{n_{z_{cg}}}{F_s}(s) = \frac{KG_1 N_3}{1 + KG_1 H}$$

$$= \frac{\frac{V}{g}\,\frac{1}{T_{\theta_2}}\,KM_\delta}{1 + KM_\delta K_g K_0}\qquad \frac{1}{s^2 + 2\hat{\zeta}_{sp}\,\hat{\omega}_{sp}\,s + \hat{\omega}_{sp}^2}$$

(A. IV-6)

where $\hat{\zeta}_{sp}$ and $\hat{\omega}_{sp}$ are the closed-loop damping ratio and undamped natural frequency, respectively. They are given by:

$$2\hat{\zeta}_{sp}\,\hat{\omega}_{sp} = \frac{2\zeta_{sp}\,\omega_{sp} + 2\zeta_1\omega_1\,KK_g\,M_\delta K_0}{1 + KK_g\,M_\delta K_0} \qquad \text{(A. IV-7)}$$

$$\hat{\omega}_{sp}^2 = \frac{\omega_{sp}^2 + KK_g\,M_\delta K_0\,\omega_1^2}{1 + KK_g\,M_\delta K_0} \qquad \text{(A. IV-8)}$$

From (A.IV-6), it is clear that if $\zeta \geq 1$

$$\left|\frac{n_{z_{cg}}}{F_s}(j\omega)\right|_{\omega \geq 1\ \text{RAD/SEC}} \leq \frac{\frac{V}{g}\,\frac{1}{T_{\theta_2}}\,KM_\delta}{1 + KM_\delta K_g K_0}\qquad \frac{1}{\hat{\omega}_{sp}^2}$$

and we may set the desired stick force per g to be N

$$\frac{\frac{V}{g}\,\frac{1}{T_{\theta_2}}\,KM_{\delta}}{\left(1 + KM_{\delta} K_{g} K_{0}\right)\hat{\omega}_{SP}^{2}} = \frac{1}{N} \tag{A. IV-9}$$

Solving equations (A. IV-7), (A. IV-8), and (A. IV-9) for K_0, K_g, and KM_{δ} yields the desired equations (6-17a) through (6-17c).

$$K_{0} \triangleq \frac{\ell}{g}\,\frac{K_{n}}{K_{g}} = \frac{\left(\hat{\omega}_{SP}^{2} - \omega_{SP}^{2}\right) + \left(2\zeta_{SP}\,\omega_{SP} - 2\hat{\zeta}_{SP}\,\hat{\omega}_{SP}\right)\left(\frac{K_{\alpha}}{K_{g}} + \frac{1}{T_{\theta_2}}\right)}{\left(\hat{\omega}_{SP}^{2} - \omega_{SP}^{2}\right)\left(2\hat{\zeta}_{SP}\hat{\omega}_{SP} - \frac{1}{T_{\theta_2}}\right) + \left(2\zeta_{SP}\,\omega_{SP} - 2\hat{\zeta}_{SP}\,\hat{\omega}_{SP}\right)\left(\hat{\omega}_{SP}^{2} - \frac{V}{\ell}\,\frac{1}{T_{\theta_2}}\right)} \tag{6.17a}$$

$$\overline{KM}_{\delta} K_{g} = \frac{2\zeta_{SP}\,\omega_{SP} - 2\hat{\zeta}_{SP}\,\hat{\omega}_{SP}}{\left(2\hat{\zeta}_{SP}\hat{\omega}_{SP} - \frac{1}{T_{\theta_2}}\right)K_{0} - 1} \tag{6.17b}$$

$$\overline{KM}_{\delta} = \frac{1}{\frac{V}{g}\,\frac{1}{T_{\theta_2}}}\,\frac{\hat{\omega}_{SP}^{2}}{N}\left(1 + \overline{KM}_{\delta} K_{g} K_{0}\right) \tag{6.17c}$$

LIST OF SYMBOLS

$B\omega$ or ω_B = Bandwidth; the frequency at which the phase angle of the θ/θ_c transfer function = -90 deg (rad/sec)

$(B\omega)_{min}$ = The value of the closed-loop bandwidth which the pilot is trying to achieve in precision tracking tasks (rad/sec)

$\bar{c}$ = Wing mean aerodynamic chord (ft)

C_L = $\frac{L}{\bar{q}S}$ Airplane lift coefficient

C_{L_α} = $\frac{\partial C_L}{\partial \alpha}$ (1/rad)

$C_{L_{\delta_e}}$ = $\frac{\partial C_L}{\partial \delta_e}$ (1/rad)

C_m = $\frac{M}{\bar{q}S\bar{c}}$, Airplane pitching moment coefficient

C_{m_α} = $\frac{\partial C_m}{\partial \alpha}$ (1/rad)

$C_{m_{\dot{\alpha}}}$ = $\frac{\partial C_m}{\partial \left(\frac{\dot{\alpha}\bar{c}}{2V}\right)}$ (1/rad)

C_{m_q} = $\frac{\partial C_m}{\partial \left(\frac{q\bar{c}}{2V}\right)}$ (1/rad)

$C_{m_{\delta_e}}$ = $\frac{\partial C_m}{\partial \delta_e}$ (1/rad)

dB = Decibel units for Bode amplitude, where amplitude in dB = 20 $\log_{10}$ [amplitude]

$\left(\frac{dA}{d\chi}\right)_{ad}$ = Rate of change of Bode amplitude with phase for the airplane plus pilot time delay at ω = $(BW)_{min}$ (dB/deg)

F_{AS} = Aileron stick force, positive to the right (lb)

F_{RP} = Rudder pedal force, positive for right rudder (lb)

F_s = Elevator stick force, positive for a pull (lb)

$\frac{F_s}{n}$ or N = Steady-state stick force per unit normal acceleration change, at constant speed (lb/g)

$\frac{F_s}{\theta_e}$ = Transfer function of the pilot model

g = Acceleration of gravity (ft/sec^2)

h = Altitude

I_y = Moment of inertia about airplane y axis (slug-ft^2)

K_α = $\delta_e / \Delta\alpha$

$K_{B\omega}$ = Pilot gain at $\omega = (BW)_{min}$ (lb/deg)

K_f = δ_e / δ_{e_c}

K_p = Steady-state pilot gain (lb/deg)

K = Forward loop gain (deg/lb)

K_c = $S\tau / I_y$

K_i = Inverse of integral time (rad/sec)

K_q = δ_e / q

K_θ = Gain of airplane's θ/F_S transfer function $\left(\frac{\text{deg/sec}}{\text{lb}}\right)$

l = Distance of forward mounted accelerometer ahead of c.g. (ft.)

l_p = Distance of the pilot's station ahead of c.g. (ft.)

l_V = Distance of angle of attack vane ahead of c.g. (ft.)

L = Airplane lift, positive for positive angle of attack (lb)

L_α = $\frac{\bar{q} S C_{L_\alpha}}{mV}$ (1/sec)

L_{δ_e} = $\frac{\bar{q} S C_{L_{\delta_e}}}{mV}$ (1/sec)

m = Mass of airplane (slugs)

M = Airplane pitching moment, positive nose up (ft-lb)

M = Mach number

$M_{F_s} = M_{\delta_e}\left(\frac{\delta_e}{F_s}\right)_{ss}$ (1/sec^2)

$M_\alpha = \dfrac{\bar{q} S \bar{c} C_{m_\alpha}}{I_y}$ (1/sec^2)

$M_{\dot{\alpha}} = \dfrac{\bar{q} S \left(\frac{\bar{c}^2}{2V}\right) C_m}{I_y}$ (1/sec)

$M_{\delta_e} = \dfrac{\bar{q} S \bar{c} C_{m_{\delta_e}}}{I_y}$ (1/sec^2)

$M_q = \dfrac{\bar{q} S \left(\frac{\bar{c}^2}{2V}\right) C_{m_q}}{I_y}$ (1/sec)

$N = F_s/n$ (lb /g's)

n = Normal acceleration at c.g., positive for a pull up (g's) (n = 1 for level flight)

$\frac{n}{\alpha}$ = Steady-state normal acceleration change per unit angle-of-attack change, when the airplane is maneuvered at constant speed (g's/radian)

$\bar{q} = \frac{1}{2}\rho V^2$, Dynamic pressure (lb/ft^2)

q = Airplane pitch rate about y body axis; for wings-level flight $q = \dot{\theta}$

q_m = Airplane pitch rate, measured at sensor

s = Laplace operator (1/sec)

S = Wing area (ft^2)

t = Time (sec)

τ_L or τ_{p_1} = Time constant of pilot's lead element

T_p = Phugoid period (sec)

V_{ind} = Trimmed indicated airspeed (knots)

V = Trimmed true airspeed (ft/sec)

Z_α = $\frac{\rho S V^2 \ell}{2m}(-C_{L_\alpha} - C_D)$

Z_{δ_e} = $\frac{\rho S V^2}{2m} C_{m_{\delta_e}}$

α = Airplane angle of attack, positive for relative wind from below (rad)

α_V = Airplane angle of attack as measured at sensor, uncorrected for position error or local flow conditions.

β = Airplane angle of sideslip, positive for relative wind from right (rad)

Δ = Increment of specified parameter

δ_{as} = Aileron stick deflection at grip, positive to the right (in.)

δ_e = Airplane elevator deflection, positive trailing edge down (rad)

δ_{ec} = Commanded elevator deflection

δ_{RP} = Rudder pedal deflection, right rudder is positive (in.)

δ_s = Elevator stick deflection at grip, positive aft (in.)

$\left(\frac{\delta_e}{F_s}\right)_{ss}$ = Steady-state gearing between elevator deflection and elevator stick force (rad/lb)

$\left(\frac{\delta_e}{\delta_s}\right)_{ss}$ = Steady-state gearing between elevator deflection and elevator stick displacement (rad/in.)

ζ_d = Dutch-roll damping ratio

ζ_p = Phugoid damping ratio

ζ_{sp} = Short-period damping ratio

ζ_3 = Damping ratio of second-order control system lag

ζ_ϕ = Damping ratio of second-order numerator term in bank-angle-to-aileron transfer function

θ	=	Airplane's pitch attitude with respect to horizon, positive nose up (deg or rad)
θ_c	=	Commanded change in airplane pitch attitude (deg or rad)
θ_e	=	$(\theta_c - \theta)$, Error between the commanded pitch attitude and the airplane pitch attitude (deg or rad)
$\frac{\theta}{F_s}$	=	Constant-speed transfer function of θ to F_s for airplane plus control system
$\frac{\theta}{\theta_e}$	=	Open-loop transfer function of airplane plus control system plus pilot
$\frac{\theta}{\theta_c}$	=	Closed-loop transfer function of airplane plus control system plus pilot
$\left\|\frac{\theta}{\theta_c}\right\|_{max}$	=	Magnitude of resonant peak in the θ/θ_c Bode amplitude plot (dB)
$\left\|\frac{\ddot{\theta}}{F_s}\right\|_{max}$	=	Maximum Bode amplitude of $\frac{\ddot{\theta}}{F_s}\left(\frac{\text{rad/sec}^2}{\text{lb}}\right)$
ρ	=	Air density (slug/ft^3)
σ	=	Real part of $s = \sigma + j\omega$
τ_1	=	Time constant of control system lead element (sec)
τ_2	=	Time constant of control system lag element (sec)
τ_{P_1} or T_L	=	Time constant of pilot's lead element
τ_{P_2}	=	Time constant of pilot's lag element
τ_R	=	Roll mode time constant (sec)
τ_S	=	Spiral mode time constant (sec)
τ_{θ_2}	=	Airframe lead time constant in θ/F_s, transfer function (sec)
$\left\|\frac{\phi}{\beta}\right\|_d$	=	Absolute value of control-fixed roll-to-sideslip ratio evaluated at $\omega = \omega_d$
ω	=	Bode frequency (rad/sec)
ω_B	=	See BW

ω_c = Gain crossover frequency, where the open-loop Bode amplitude curve crosses 0 dB line (rad/sec) or filter corner frequency

ω_d = Dutch roll undamped natural frequency (rad/sec)

ω_{fs} = Undamped natural frequency of feel system (rad/sec)

ω_{n_z} = Corner frequency of n_z filter

ω_{sp} = Short-period undamped natural frequency (rad/sec)

ω_3 = Undamped natural frequency of second-order control system lag (rad/sec)

ω_α = Corner frequency of $\Delta\alpha$ filter

ω_ϕ = Undamped natural frequency of second-order numerator term in bank-angle-to-aileron transfer function (rad/sec)

$| \;\; |$ = Signifies Bode amplitude of a transfer function

$\measuredangle$ = Signifies Bode phase angle of a transfer function

$\measuredangle_{ad}$ = Phase angle of the airplane plus pilot time delay at $\omega = (BW)_{min}$ (deg)

$\measuredangle_{pc}$ = Phase angle of the pilot compensation at $\omega = (BW)_{min}$ (deg)

$(\dot{\;}) = \frac{d(\,)}{dt}$ = First derivative with respect to time

$(\ddot{\;}) = \frac{d^2(\,)}{dt}$ = Second derivative with respect to time

$(\hat{\;})$ = Hat symbol indicates desired value of parameter

Subscripts

T Denotes the basic NT-33A airframe

c.g. Center of gravity

SS Steady State

ABBREVIATIONS

ACM	Air combat maneuvering
CAS	Control augmentation system
c.g.	Center of gravity
F.C.	Flight condition
FCS	Flight control system
IFR	Instrument flight rules
ILS	Instrument landing system
KIAS	Knots indicated airspeed
KTAS	Knots true airspeed
Log	Logarithm to base 10
PIO	Pilot-induced oscillation
PIOR	Pilot-induced-oscillation rating
PR	Pilot rating (Cooper-Harper scale)
SAS	Stability augmentation system
SCAS	Stability and control augmentation system
USAF	United States Air Force
VFR	Visual flight rules
VSS	Variable stability system